AMERICAN GEOLOGY,

CONTAINING A

Statement of the Principles of the Science,

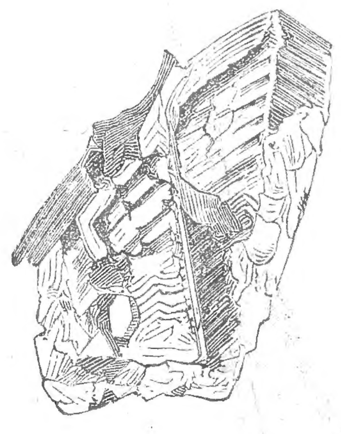
WITH FULL ILLUSTRATIONS OF

THE CHARACTERISTIC AMERICAN FOSSILS.

TO BE PUBLISHED IN FOUR PARTS, WITH AN ATLAS AND A GEOLOGICAL MAP OF THE UNITED STATES.

BY EBENEZER EMMONS.

PART I.



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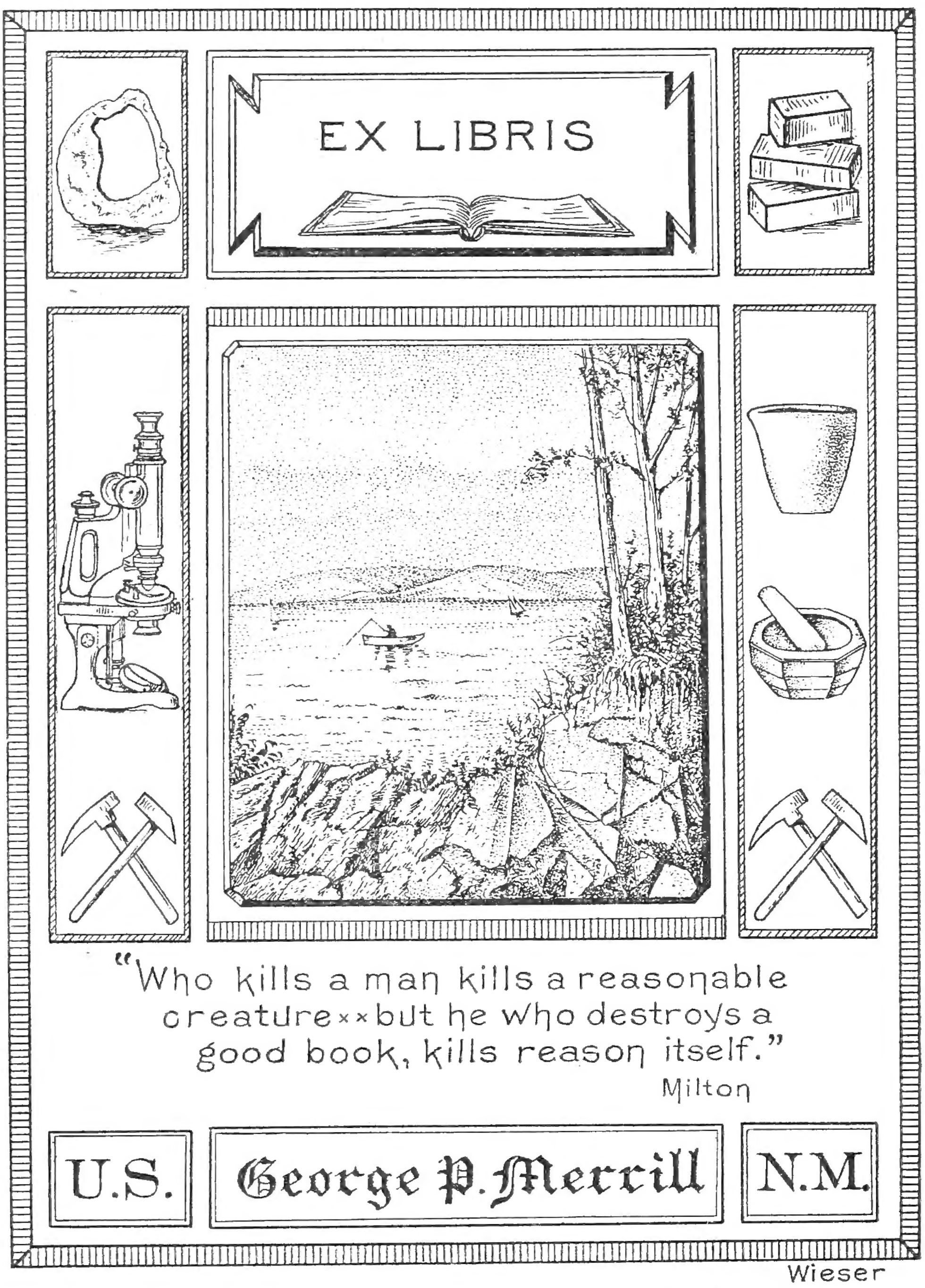

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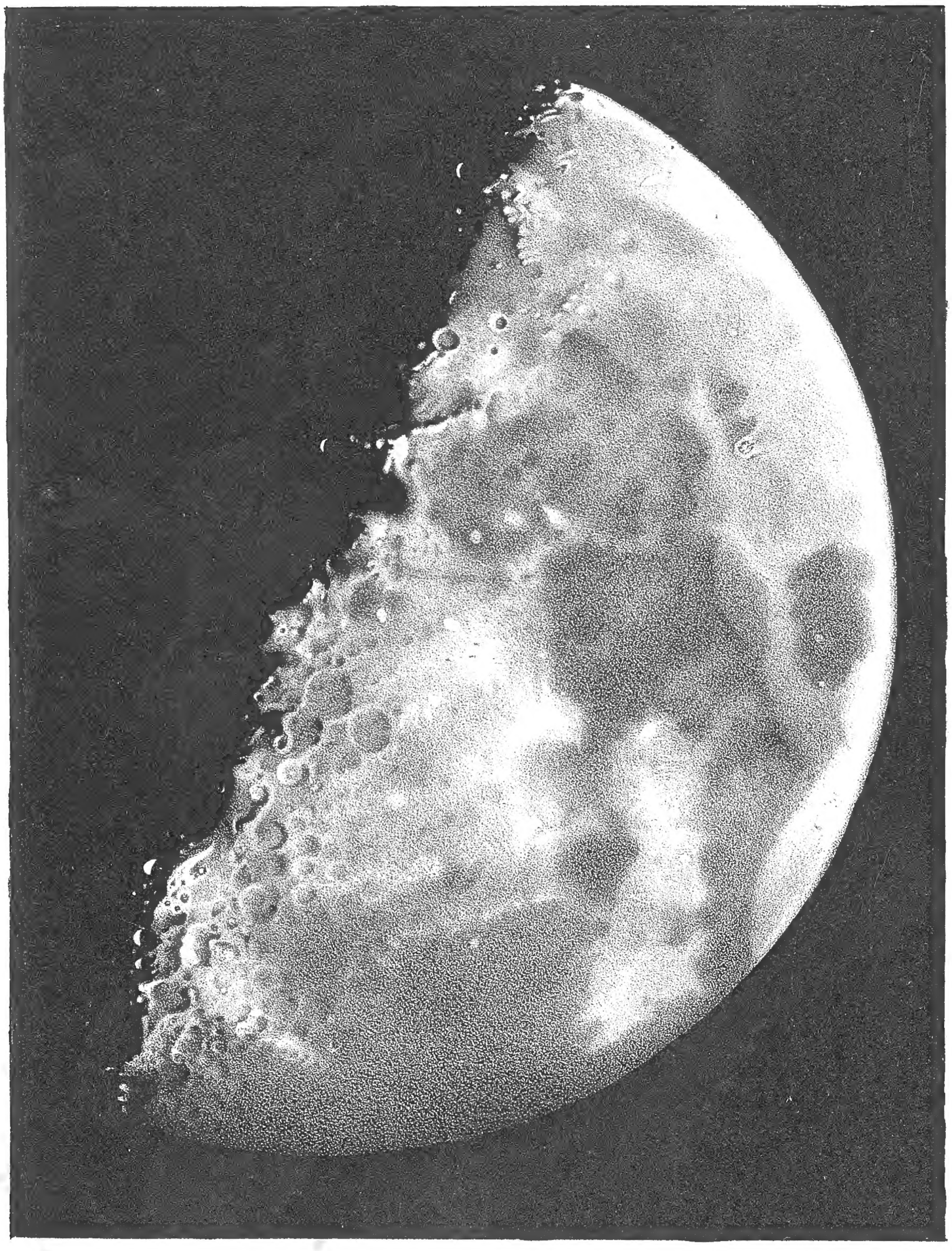

AMERICAN GEOLOGY.

PRELIMINARY REMARKS.

§ 1. The science of geology is of recent origin. The first attempts which were made towards the construction of a system, date no farther back than the middle of the last century. In its progress it has undergone many changes, as has every other science dependent upon observation and experiment.

The object of geology is to give a rational explanation of the structure of the earth. To accomplish this, it examines the phenomena presented at the surface of the earth, and its interior, where it is accessible; and it attempts to discover the causes of those phenomena, and to find the true reason for their existence, and also to fix the dates when remarkable changes occurred. The advantages resulting from the study of geology are numerous. It gratifies a laudable curiosity; it informs us where we may find the most valuable natural productions, as coal, salt, iron, gold, silver, manganese, copper, lead, marble, and many other useful substances; it enlarges our views of the field of nature; it enables us, by our knowledge of the present, to look far backward into the past; it reveals to us a vast duration whose limit we can not fix—a succession of changes in the physical condition of the earth, which exhibit a progress towards an ulterior end which seems to have had reference to the existence and well being of man. We see in the earth's changes, and its brute inhabitants, a progressive movement along an upward scale, not in a direct track, but rather in the ultimate results. It teaches us that order has prevailed in the operations of the natural elements through the lapse of ages—

that there was a plan in the divine mind which has been working with a special reference to the good of our race; and lastly, that the plan of creation, and its scheme of construction, belongs to but one system, however far we may go back into the past. All our observations respecting the past and present lead to the conclusion that the plan of creation is one—that the laws and forces which are now in operation have been the same from the beginning: therefore, the true method for an interpretation of the past, is by those laws and forces which govern the present.

§ 2. Our knowledge of the earth is confined to the earth's crust, by which we mean to include all that part which is accessible to human observation. This part is the theatre upon which geological events have been acting from remotest periods, and still it is safe to draw inferences respecting phenomena belonging to the deeper seated parts, provided they are in accordance with established principles, or with what we know.

§ 3. The earth's crust is composed of rocks, in which term geologists include not only consolidated materials, but sands, clays, soils, and fluids. Strictly speaking, the earth's crust is composed of rock and water. We might perhaps reckon also the free gaseous bodies confined in caverns, which, under favorable circumstances, escape into space, as atmospheric air, carbonic acid, nitrogen, and ammonia; or they may be regarded as things contained in the crust, and as agencies through whose force and power the solid crust has changed its phases in time and its position in space. Heat should be added to the foregoing; it operates *per se*, and gives activity and life to the liquids and gases which permeate the crust and fill its empty spaces.

§ 4. The monumental records of the past are of two kinds, the physical and the organic. To the former belong the impress of the movements of the earth's crust upon itself, or upon the different strata which were deposited in different periods; to the latter, the preservations of plants and animals. Their remains occur in groups, and represent the forms of the differ-

ent periods. No two periods are represented by similar groups, and their dissimilarity is practically important, furnishing the facts by which the periods themselves may be distinguished from one another. It is also an interesting feature in a historical sense, proving by comparison a progression in development along the measures of an ascending scale. The periods as they approach the present are represented by plants and animals more akin to the living, while in the more remote their resemblances as a whole are less. Notwithstanding this, the four types of the living are represented in the successive periods, with the exception of the first.

§ 5. Prior to the creation of plants and animals there was a period very clearly marked by the reign of physical forces; it is azoic, and the rocks of this period have no parallel—they are all crystalline. Heat was the predominant and active element. Stability and form was given to the earth in this period, principally by the escape of heat into space; and condensation of aqueous vapor upon a cooling crust, gave origin to the surface waters of the globe. Seas and oceans were formed in all the basins and great depressions, and the culminating points gave origin to streams which flowed oceanward; but the oceans, ere the waters had filled their bosom, began to lose their contents by the vaporization of this new element. When it had saturated the atmosphere, it fell again to the earth. Thus began that vast machinery by which the earth is supplied with rain and dews. It has known no suspension. The vapors rise upward, and the streams flow onward in perpetual cadence. At this stage the consolidated crust begins to wear, and its debris also begins to be transported and borne onward, and its progress is only arrested by the plains and depressions, where it accumulates, giving origin to another class of rocks whose parentage is indicated by rounded particles and masses. The activity of fire diminishes—that of water increases. The two forces are antagonistic of each other. One levels the surface, the other breaks it up; the first is constant in its action, the latter is paroxysmal. The fire slumbers longer, but never

expires. It has retired more inward toward the earth's core, and it is girt about by stronger and stronger bands; but it yet preserves its outward vents, and often warns us of its power in the trembling of its bands and the molten rocks which flow from the fire chasms which it opens.

The interpretation of the varied phenomena to which we have just alluded, must be in accordance with human experience and observation. Observations turned to those phenomena which belong to each of the periods in the earth's history, prove that the plan of creation—the ideas which that plan expresses—is a unity. It proves more than this, that the present is only a part of the past, and belongs to it. As the whole of a thing is made up of its parts, and is imperfect in the absence of one, so the present is imperfect without the past, and the past would be imperfect without the present. The interpretation of the present is perfected only by reference to the past, and the past would be unintelligible without the present. Each period then is a fragment; but the present is a greater fragment than all the past put together. The present does not date its beginning with man, but with the earliest species of plants and animals which now live, and whose primordial forms are not as yet extinct.

§ 6. The life of plants and animals is controlled by a single element; that is oxygen. The adaptation of organs is in accordance with its properties. It has always been so. We presume, too, that its supply has been constant—that there has been no period when its quantity was either greater or less than it is now. A different view is not sustained by the fact that at one period huge lizards predominated in its fauna, for analogy proves that this class would have perished with a less proportion than that which exists in our atmosphere at the present time.

In cases of this kind reasoning from special structural affinities to general physical conditions is not always safe. The lias and oolitic periods abound in the remains of cold-blooded animals, whose respiratory apparatus was undoubtedly imperfect, like the

lizards of the present. It is a favorite inference with a certain class of the progressive geologists, that the oxygen of the atmosphere at that period was less in proportion to its mass than it is now. But then may we not inquire, if there was less oxygen in the present atmosphere than there actually is, could the membranous reptile lung supply the demands of the system; and is not the constituent proportion of oxygen the quantity required to give the creature the power to breathe at all? I say it is not always safe to reason from structural affinity to physical conditions. If we take any other organ, as the eye, and draw from its structure and condition analogous inferences concerning the quantity of light, we may see where it will lead us. A class of progressive geologists, maintaining that in the early periods of life the light of the globe was dim, and that but few rays shone through the hazy atmosphere, find in support of this doctrine the fossil remains of a fish or a lizard with enormous eye sockets. He believes that the large eye was adapted to a dim state of the atmosphere. Another person finds a fossil with very small bony sockets. In this case, too, it may be said the eye was very small, and hence it was adapted to an exceeding intense light—to the sun when it shone fiercely from its throne in the heavens. But again, a fossil is found entirely destitute of an eye socket, and not a vestige of an organ of vision can be found; hence there was a time when the earth was shrouded in darkness, for in darkness animals have no need of eyes, and light would be useless to animals destitute of the visual organ. But then we find all these states of the eye in the present arrangements for supplying the world with light. The Pomatomus telescopium, a fish of the Mediterranean, which lives in very deep water, has a remarkably large eye. It is the position which it occupies that requires the large eye, and that large eye is adapted to its abode; and if only one-half of the light of the sun was extinguished, it probably would be unable to see at all. And just so with the reptile, if one-half of the oxygen of the atmosphere was withdrawn from it, all reptiles would die. The mole has a very small eye, but that

small eye would be of no use if the ground was lighted by fewer rays. The blind fish and the blind animals of the mammoth cave live in a period when the earth is lighted up most gloriously: their abodes are dark, but yet the sun shines without in all its strength. We find, then, all conditions of the eye and the lungs at the present time. But it does not follow, that because the structure of the fossils of a given period may be found whose organs belong to a certain type, that the physical conditions of the earth were materially different from what they are now. This view of the subject does not conflict with the doctrine of adaptation, but rather sustains it. The physical conditions are first established; the organic kingdoms afterwards come in with their separate adaptations. The organisms are perfect in their adaption to the conditions in which they are to live, as well as to the position in space, and the mediums in which they are to be placed. The doctrine of progressive development, as usually represented, seems to be untrue. It proceeds on the ground that the earliest beings were the least perfect, and that progression consisted in the creation of those animals which were more perfect in their structures than their predecessors. But who can not see that the world is full of the same imperfections in animals now as in the beginning. Progression has no reference to perfection of structure, but to rank. Structures have been always perfect, but rank has been progressive.

§ 7. Water acts upon the earth's surface in many ways. It is a solvent. Temperature and pressure modify this property. Pressure and temperature combined increase it to an indefinite amount. It also acts mechanically. It permeates the solids and penetrates the fissures of rocks, and in the cold regions divides asunder the particles and masses in freezing. It is a carrier or transporter of the divided matter. Flowing in streams over the surface, it carries along from the higher to the lower levels the broken-down matter. When moving in masses, in the form of tides and waves of seas and oceans, it bears away and moves to distant points the mud and sand com-

mitted to it; as a body moving in great ocean rivers, as the Gulf stream, it also bears these materials forward to certain and well determined regions. It thus arranges and moulds the ocean's bottom from the matter committed to it by the terrestrial rivers. By mechanical force the waves break down the strong rocky barriers of coasts, as well as those shores which are girded with sand. The ocean then is a moulder and distributer of all the plastic matter committed to its bosom. In fine, moving water, under whatever name it has received, whether rivers, waves, tides, or ocean currents, is both destructive and constructive, according to the conditions and circumstances of the moving mass.

The changes of temperature which a country undergoes, and the amount of rain which it receives, produce important changes in the physical condition of its surface. The observations which have been hitherto recorded are however too few to become the basis of important geological reasoning; yet they are sufficiently so to require some notice in this place. The following facts are recorded in the periodicals of the day, and are among the most important of this class:

Latitude.	Place.	Mean an. temp.	Rain in inches.
	Huntsville (9 years), ...		51·13
	Natchez (8 years), ...	64·76	
	Columbia, S. C., ...	56·8	49·90
	Washington, D. C., ...	56·57	
39° 56′	Philadelphia, ...	53·42	
39° 06′	Cincinnati, 510 ft. above tide water, ...	53·78	
41° 14′	Hudson, Ohio (3 years,) 9 A. M., ...	48·7	37·63
	(The amount of rain varies some nine or ten inches.)		
	The average at 3 P. M., ...	55·6	
	Trenton, N. J., ...	48·22	
	For six summer months, ...	60·60	
	Winter months, ...	35·79	
	Prevailing winds S. W.		
	State of New York—		
40° 37′	Flatbush, L. I., ...	51·25	
41° 30′	Newburgh (17 years), ...	48·96	35·54
	Albany, do	48·27	39·91

Latitude.	Place.	Mean an. temp.	Rain in inches.
	Rochester, 620 ft. above tide water (11 years),	47·48	27·16
	Barometrical mean, 29·56 in.		
	Range, 1·34		
	Malone,	52·66	
42° 42′	Penn Yan (16 years),	46·87	27·8
43° 6′	Utica 437 ft. above tide water (5 years),	46·35	44·12
	Barometrical mean, 29·64 in.		
	Range, 2·03		
	Syracuse—barometer (400 feet), 29·33		
	Range, 2·26		
	Salem, Mass. (33 years),	48·65	
	Williamstown, 595 ft. above tide water (23 years),	45·59	37·48
			Snow in inches.
	Montreal (3 years),	41·07	65·85
			Rain in inches.
	do		18·60
	Warmest day, +90		
	Coldest, —13		
46° 47′	Quebec, 340 ft. above tide water,	37·19	
	Detroit,	52·66	32·79
	Brunswick, Me. (11 years),	.....	37·15
	Mean temperature for latitude of 41° 43′,	49·75	
	do do do 42° 43′,	48·15	

Decrease of temperature by elevation, one degree for every 325 feet, for New York.

Mean temperature for the state of New York, reduced to the standard of Albany and level of the sea, 48·95.

Mean quantity of rain, in inches, 39·55

Mean quantity of rain for places near the lakes, and western courses, 24·52 inches. Thus Lewiston has only 20·40 inches of rain, Ogdensburgh 24·61 inches, and Rochester only 28·69 inches.

The area of the state of New York is 48,000 square miles. I have no observations which show how much of the rain evaporates, and how much passes off in drainage. The tributaries of the Ohio river* rise over an area of 24,337 square

* Smithsonian Contributions, by Charles Ellet, jr., Civil Engineer.

miles. Here the total annual fall of rain is approximately thirty-six inches. Forty per cent of this quantity passes off in the drainage of the branches above Wheeling; sixty per cent is evaporated, or is employed by the vegetable kingdom. The average discharge of the Ohio at Wheeling for six consecutive years, was found to be 835,323,000,000 cubic feet. The quantity of solid matter which this quantity of water holds suspended in a cubic foot, is approximately $\frac{1}{14600}$ part.

The quantity of rain which a country annually receives is connected with the amount of degradation which that country is undergoing; and the amount of matter dissolved out of the exposed surfaces of limestone and other rocks, is also related to the quantity of rain which flows over its surface. The quantity of carbonic acid and ammonia which is required to confer fertility upon a country, stands connected with the number of inches of rain with which that country is supplied. When observations have been made upon the quantity of rain which a given area receives annually, together with the amount of sediment which drainage carries away, it will be possible to form an approximate calculation of the rate the degradation is going on, as well as the rate at which the valleys are filling up. There are also many other problems which will receive a solution when the related facts or data shall have been obtained.

Questions of a practical kind, and which are closely related to geology, are constantly arising; and upon their answer some of the most important interests of society are involved. For example, our rivers overflow their banks, and inflict heavy damages upon private and public property. Can any practical scheme be devised, by which these injuries shall be avoided or prevented? Can those streams be controlled so far as to render their swellings harmless. We have a natural illustration how nature sometimes counteracts her own evils: the Androscoggin, when in flood, flows through a short cut into Umbagog lake. Hence, its waters being partially diverted for a time, finally pass down to the ocean harmlessly. In a valuable treatise on the physical geography of the Mississippi valley, by Mr.

Charles Ellet, he proposes to put in execution an analogous plan, to distribute the waters of the Ohio in a more equable manner by means of reservoirs, so as to preserve a given quantity on its bar at Wheeling. It must be noted, that in the execution of all similar projects certain geological results will follow. The detritus will be arrested in artificial basins; the stream, in its onward course, will be freed in part from sediment; the accumulations which have been collecting at the mouths of rivers and in shallow ground, will be diminished in quantity, and their nature somewhat changed. The changes which improvements in navigation by dams, by diversion of streams by canals, are and quite important. These changes are not confined to the sediments. Certain species of fish become more widely distributed by means of channels of communication being opened between the lakes in the interior of the country and its coasts. The proteus of lake Erie has found its way to the Hudson river by the Erie canal, and the different species of limneas and unios now occupy its bed throughout its whole extent.

§ 8. Notwithstanding the great extent of land, the North American continent is well watered. This is especially true of the United States. Situated between two oceans, it has a breadth of 2500 miles of land. The great western lakes are inconsiderable areas compared with the wide interval between the oceans. From the gulf of Mexico to the great lakes, or country of lakes, it is 1200 miles by the shorter route.

Notwithstanding the great area of unbroken soil, the distribution of the forces which supply water to 2,500,000 square miles is such, that the whole country can be traversed and cultivated. It is true that at the base of the Rocky mountains there is an arid country—one too dry to be inhabited. The westerly winds which are known to prevail in this country, are deprived of a large proportion of their water by the ranges intervening between this dry country and the Pacific ocean.

Taking the whole globe into view, we may learn by an inspection of its map, that land and water are unequally dis-

tributed. As it regards the area of land, it is found that the northern hemisphere contains three times as much as the southern; and as it regards the expanse of water, its superficial area in the southern exceeds that in the northern hemisphere.

§ 9. The Atlantic ocean is prolonged north and south so as to extend from pole to pole, while its breadth does not exceed 5000 miles. Its depth has been stated at about three miles; its area is 20,000,000 square miles. The Pacific ocean is prolonged from east to west. If measured on a line extending from Peru to the eastern coast of Africa, it is 16,000 miles. This great expanse of waters contains 70,000,000 of square miles, exclusive of the areas which are occupied by its islands. Its depth is four miles; but many points have not been fathomed even with lines six miles in length. The sounding in all waters, whether oceans or seas, or inland fresh and salt water lakes, demonstrates that their bottoms possess all the diversities of surface as the land, sinking in many places to profound and unfathomed depths; in others, banks and terraces spread out far and wide. These banks or terraces are probably made by the joint operation of the waves and of submarine and superficial currents, which are common to all great bodies of water.

The area of dry land does not exceed 35,500,000 of square miles. Its mean elevation is about 1000 feet; hence it follows that the entire surface of dry land may be covered with water. The great disproportion of dry land to water is a provision which is necessary to the well being of plants and animals.

§ 10. If water covers four-fifths of the earth's surface, it is evident that its influence, as a geological cause, should not be overlooked. The North American continent being skirted by two great oceans, and being supplied also with large inland lakes, and the largest and longest water courses in the world, we may expect to find those phenomena which are due to aqueous action upon the grandest scale; while the other element, volcanic fire, seems to be so far exhausted in its power in the United States, that it is impossible to obtain specimens for laboratory illustration. The Atlantic coast is remarkably

indented. The coast of Maine, Massachusetts, and Connecticut is deeply gashed and serrated. The southern coast and shores are penetrated by deep bays. The Chesapeake and Delaware are two of the most important. The inshore sea, which has received the name of sound, is another feature of the coast which may properly claim attention. Long Island, Albemarle, and Palmico are the largest. These sounds have inlets which are liable to be closed by coast storms; or on the contrary, new inlets may be formed by the action of winds and waves upon a sandy barrier. For this reason, the sounds upon the coast of North Carolina vary much in the amount of their saline matter; for this reason, too, they undergo changes in their marine faunas. No fact, however, so conclusively proves the variable condition of the ground occupied by these sounds, as the fact that their bottoms are everywhere studded with the stumps of the common pines of the country. The grounds which may be selected for fishing, require the removal of these stumps by gun powder before a net can be drawn. At the first view it may be inferred that the bottoms of the sounds were dry land but very recently; but the stumps of pine, when immersed in water, are almost imperishable, lasting for centuries: still, geologically speaking, the pines belong exclusively to the present, as they are evidently the same species of pines as those which now live upon the coast.

The coast is protected by belts of sand, which in time support a stunted vegetation, and admit of pasturage for mules, horses, and sheep. The horses which run wild upon those semi-deserts belong to the pony breed; but they are tough and hardy. They invariably refuse corn when first taken. The sand reefs and barrens are entirely due to the action of winds and waves. The sands are constantly accumulating along the coast line. Portions of wrecks, fish-spears, coins from wrecked vessels, wash upon the beach after due time. These facts illustrate the action of the waves. This coast, by the incessant action of its waves, has traveled eastward two hundred miles since the Eocenic period. Cape Hatteras moves in advance of

the general coast line. The inclination of the Eocenic plain is equal to one foot per mile. It extends inward to Raleigh, which is two hundred feet above the sea level. Upon the Atlantic coast we learn the nature of the action of water moving in wave masses. The slope of the beach is gentle to the surf line; here the bank steepens, and the crested wave rotates vertically upon itself, giving origin to the ground wave or undertow, while a portion shoots forward in thin sheets, rippling the sands over which it flows. Upon the Carolina coast this action is mainly constructive.

§ 11. The constructive action of water is equally manifest in the formation of shoals. The tide-wave, which travels northeast, transports detritus, which is deposited at any point where an obstruction lies in its way. A portion of a wreck is sufficient to form a shoal.

§ 12. It has been said already that the bottoms of oceans and seas are not spread out in level plains. They have all the diversities of dry land, rising in some places into mountains and hills; in others, sinking into deep valleys. It is in these deep valleys that sounding lines fail to reach the bottom. Extensive and comparatively level banks exist, where the water has only a moderate depth. The Atlantic's shore is skirted by extended ridges, which are formed or moulded by the joint action of tides and waves.

§ 13. Animals live upon the ocean's bottom; but different kinds inhabit it at different depths. They are rarely found living below the depth of 180 feet. Vegetables grow in the ocean. They can subsist at the depth of 300 feet. The most favorable positions for animals and plants are near the shore, where the water is comparatively shallow. In deep water they select the slopes of ridges. The summits are generally avoided on account of the disturbance by waves. Great pressure, and the absence of light in deep water, are unfavorable to life; and the more profound abyses, like the heights of the Himalaya and Andes, are dreary wastes—the one from its darkness and pressure of the superincumbent water, the other from its exces-

sive cold and thin atmosphere. The causes which are now operative in excluding animals and vegetables from deep sea bottoms and high mountains, have also been operative in all periods of the earth's history.

§ 14. The earth's surface did not receive its present configuration at its creation. Its mountains and valleys had no existence in the original constitution of the globe. Even its highest mountains, the Himalayas, have been raised long since animals and vegetables were created; and oceans but lately rolled over lands which are now the highest points of continents. Powerful agents have therefore been operative in these changes. The most effective of these agents are water and fire. Water is operative in many ways. It is a solvent of many of the materials composing the earth's crust. The rocks are dissolved by water. It is the most effective when aided by heat and pressure. In the deep parts of the earth's crust, where there is both heat and pressure to aid it, silex is dissolved; and if it rises to the surface in a heated state, and there cools, its silex is deposited upon the soil or rocks, as at the Geysers of Iceland. This deposit is called *siliceous sinter.* Cold water readily dissolves carbonic acid, which is diffused in the atmosphere and soil; and cold water, aided by carbonic acid, dissolves carbonate of lime and other carbonates, together with the oxides of iron, manganese, and phosphate of lime. Spring water, which holds them in solution below the surface and under pressure, deposits them at the surface. Incrustations of lime and porous beds of it, are formed around these springs. These deposits are called tufa or travertine. It should be noted that travertine is a rock formed on the dry land—it is a subaerial formation. Ochrey iron ore, mixed with carbonate of iron, and manganese are also deposited around springs, and upon dry land, under similar conditions. All these are subaerial deposits, and should be distinguished from the subaqueous. Water percolating through the soil, holding in solution carbonic acid, dissolves carbonate of lime and iron, which it deposits on the coarse and fine materials, when they become cemented together. They

are then less porous in structure, and consequently less pervious to water. The cemented stratum is often called hard pan. When impervious, or only partially so, water is retained too long in the soil for profitable cultivation. Beds of gravel and pebbles are also cemented under similar conditions. These are called pudding stones; they are also subaerial formations, and should be distinguished from conglomerates, which are subaqueous. Limestone, permeated in the same way, yields to the action of water. A shelving ledge, or the roof of a cave below, is often hung with pendent masses, like icicles from the eaves of a house. These are called stalactites. Their formation begins with a deposit of lime in the form of a ring, which is gradually prolonged by additions from the water. A part of the water drops to the ground or floor, and there forms another deposit of carbonate of lime. This is called stalagmite.

Numerous instances, illustrating the agency of water in the mode I have stated, are found in all parts of the Union. Thus stalactites and stalagmites occur on a large scale in all the great caves of Kentuckey, Tennessee, and Virginia; also in the smaller caves of New York in Albany and Schoharie counties. Tufa is deposited from numerous springs in Onondaga, and other western counties in New York. The hydrous peroxides of iron and manganese are derived from mineral springs formerly existing in the tertiary formations of the southern states, as well as in the more ancient rocks of the primary belts. Silica is often separated from its solution in hot water and from steam, and has furnished the siliceous sinter surrounding hot springs in almost all regions of the globe. Amethysts and coatings of chalcedony upon common quartz in Nova Scotia and the trap ranges of our country, and upon crystals of calcspar in Edwards, N. Y., were the products of hot water holding this substance in solution.

But water is more eminently a solvent for those bodies which have taste, as common salt, alum, copperas, &c. Extensive rocks are known, which consist of nearly pure salt or chloride of sodium. The elements of common salt exist in many of the

stony matters upon the earth's surface. Chemical action has separated these elements, and united them again so as to form this compound. It is dissolved by the streams, and transported to the ocean, which has become salt by small additions from time to time. The water of the ocean which is carried off by evaporation is fresh; and hence, while water continually flows in charged with a little salt imperceptible to the taste, and none is carried off, it will finally become salt. In shallow seas or bays in warm climates, where evaporation is rapid, salt is rapidly formed; and though it may be mixed with mud, yet when it crystalizes, as it always will, it becomes pure. Layers of crystals are successively formed under favorable conditions, and these united form thick beds of salt. The quantity of salt in the oceans and seas is enormous, and long periods must have passed before it became perceptible to the taste. The small quantity of salt in the water in the early periods may have modified the forms both of animals and vegetables. Brine springs may originate from beds of rock salt, or water in the deep parts of the earth's crust, and by the aid of chemical affinity may form common salt from its elements. These elements are known to exist there; and the water being charged with salt, rises to the surface as brine springs, or else the brine may remain below in reservoirs until they are reached by the industry of man. The brines or salines of New York seem to be formed in this way; that is, from the elements of salt which exist in the rocks in other combinations.

Water, then, acting as a solvent, produces many important changes upon the earth's surface. It dissolves and consolidates rocks when aided by carbonic acid, heat, and pressure. It dissolves and transports the saline bodies to the common reservoirs, where they are concentrated by one of the natural processes—that of solar evaporation. It is a result of the utmost importance to the well being of man.

Bodies of salt water are never formed so long as there is a supply of rain to maintain a drainage to the ocean. If, however, the rains only supply sufficient water to fill a basin, and

there is no discharge or surplus water, the constant evaporation of fresh water concentrates the saline matter of the lake, and in time it becomes salt. The great salt lake of Utah became saline by evaporation of its waters, the evaporation and drainage of the valley being sufficient to equalize each other.

There is a high probability that the saltness of the seas and oceans had attained a large amount of saline matter prior to the palæozoic period. The silurian system furnishes brine springs, and the fossils of this early period indicate that they were the inhabitants of the ocean. The vast quantity of salt in the oceans of the globe indicates also the lapse of long periods during which the saline matter was accumulating.

Water separates the parts of rocks from each other. This is the result of congelation; this, often repeated, ends in comminution or disintegration. Soils are comminuted or pulverized rocks. The process of comminution is more rapid on the tops of mountains. Slaty, schistose, and jointed rocks favor this result by admitting water between their lamina and joints. The broken and comminuted rocks are thus prepared for a removal to a lower level. The small but rapid streams first take upon themselves this office. A part of the disintegrated rock remains upon the tops and sides of mountains. It bears a scanty herbage, whose roots confine it more securely. The streams lose a portion of their burthen at all the levels, where small meadows are formed, and where grass springs up. The streams unite in plains below, where a rich vegetation is nourished, and where climate favors the organic kingdoms. The united mountain streams form rivers, which flow oceanward; but before they reach the great reservoirs, the tides check their currents. Here deposits are again made. Shoals are the uniform results of the meeting of river currents with the tidal wave. But the return tide favors the river current, and its detrital matter, which it has borne along, is delivered up to the ocean wave. The quantity of earthy matter which is thus transported, varies with the season. The Missouri is always muddy, and a thick deposit subsides in vessels in which it stands.

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From the foregoing facts it follows that rocks are now forming. The muddy sediments, or the sand and gravel, will in time consolidate. There are, however, no additions made to the earth's crust: the gain of one place is at the expense of another. The contribution which the mountains make to the plains, and to the ocean's bottom, is from their tops and sides; and though the plains are raised, the mountains are lowered.

§ 16. Water moving in masses, as in waves, modifies the character of the earth's surface. It is upon and near the shore that waves produce the greatest modifying effects. The long swell of waves, as they break successively upon a shore, raises the mud and fine sand, and bears it onwards to the land. The material, whatever it may be, will accumulate in ridges, which have a steeper slope on the land than upon the ocean's side. But ridges are formed also upon the shores of lakes on a scale commensurate with their size. As examples of ridges upon a large scale, I may cite Long island and its parallel outer oceanic ridge, and the ridge upon the south side of lake Ontario. These ridges are formed by the waves which bear some of the sand to its crest, when it falls over it to the land side. This is a permanent addition to the ridge. The ancient shores of lake Champlain, in Clinton county, may be traced by similar ridges of sand and gravel. There are no less than four nearly parallel ridges, which mark the former positions of the lake. These show that the land for long periods occupied positions at lower levels than at the present time, and that these changes of level have occurred since the drift period. There is generally towards the land a sheet of shoal water, which becomes a marsh, and which in time may be filled up.

Water moving in mass, in the form of tides, modifies also the earth's surface. The tide entering the mouth of a river flows up its channel, but meeting the down current of the river, it checks its flow. Some of its burthen of mud falls to the bottom, and forms a bar or a shoal. The outward tide, however, receives the rest of the burthen, and bears it oceanward, some of which may be carried to the ocean rivers. The tide of our

own coast flows northward, and carries its burthen onward; and at every opening mouth of a river it receives accessions, which, as a common carrier, it bears along, or gives it a new distribution. The conjoint actions of waves and tides are not only to carry, but break down, the bars and ridges which they have formed across inlets and bays. Bays and inlets may have been shut off from the ocean for centuries, or until their waters become fresh, and peopled with fresh water tenants, both from the animal and vegetable kingdoms. Again a high tide, accompanied with high waves and winds, breaks down the bar, when it is at once filled with salt water. The animals and vegetables of fresh water die, and are replaced by the marine. Such alternations are well established facts. These views are illustrated by the changes in Albemarle and other sounds upon our southern coast.

Water moving in masses, as in ocean rivers, modifies the present surface of the earth. These great rivers are only carriers; they take what is committed to them, but they do not furnish the matter they carry. The Gulf stream is an ocean river. The great terrestrial rivers, as the Amazon, La Plata, Orinoco, Mississippi, Ganges, and Brahmapootra, are the contributors to the ocean rivers. The density of sea water aids in the wider distribution of matter committed to it. The great river, called the Gulf stream, originates in the Atlantic. Beginning near cape Horn, it is there divided: its main current flows down the western coast of America, but it turns suddenly to the west, and is lost in the great equatorial current of the Pacific; it then crosses the ocean in the parallels of 26 and 24 N. It is 350 miles broad when it impinges upon the coast of China, the eastern peninsula, and islands of the Indian archipelago, where it is again divided. A portion is deflected to join the great equatorial current of the Indian ocean, when it is impelled by the south-east trade wind: it however maintains a westerly course between 10° and 20° parallels of south latitude. It is divided a third time by the island of Madagascar. One part bends round its northern end, and flows through the

Mozambique channel, and before doubling the cape of Good Hope is joined by the other stream, when it flows outside the Aguillas bank. It there takes the name of the South-Atlantic current. It now flows up the west coast of Africa to the parallel of St. Helena, where it is deflected by the coast of Guinea. It now forms the great Atlantic equatorial current, and flowing westward, it splits upon cape St. Roque. One stream flowing along the eastern coast of South America, its force is finally spent in southern latitudes before it reaches the straits of Magellan, except a single branch, which is deflected to the cape of Good Hope. The other branch, or the great equatorial current, flows northerly along the coast of Brazil with great force. It encounters the river currents of the Orinoco and Amazon, and yet it speeds its way to the Carribean sea and gulf of Mexico. It here gets great accessions of heat, its temperature rising to 88° 52′. It now flows up the coast of North America under the name of the Gulf stream. It is deflected to the east by Newfoundland. It is again divided into several streams: one stream flows towards Britain and Norway, and being still farther divided, a branch flows onward to Spitzbergen, where it mitigates the severity of its climate. From Newfoundland a branch strikes off for Baffin's bay. Another branch also takes a sweep southwards to the Azores, and being aided in its march by the north trade winds, it rejoins the great equatorial current. In consequence of this great bend, a vast expanse of water is left nearly motionless and stagnant, in which sea weed, trees, bodies of drowned animals, float for a time, when they are finally cast upon the shores of the Azores. The greatest velocity which the Gulf stream acquires, that of seventy-eight miles in twenty-four hours, is when it leaves the Florida straits. The rapidity of its current is variable.

Currents also flow from the antarctic and arctic circles. These bring with them icebergs. The arctic brings down icebergs to the latitude of Newfoundland, and even to the Azores. In these latitudes they are melted in the Gulf stream. In consequence of the meeting of the floating masses of ice with the warm

stream and warm atmosphere, fogs are generated, which obscure the air for great distances around. Another cold current from the Arctic sea flows inside of the Gulf stream down the coast of North America. It lowers the temperature of the coast. This effect is unfavorable upon New England, but favorable to the southern states situated upon the seaboard. These great ocean carriers, wherever they impinge upon the bottom of the sea, or upon a shore, deposit a part of their burthen. The banks of Newfoundland, St. George's bank, Sable island, have been made by contributions from the Gulf stream. While it distributes these burthens of matter, it is also a great distributer of heat. The climate of Europe and of the northern seas is mitigated by this great current carrying a warmer water than the surrounding ocean. As westerly winds prevail upon the Atlantic, the coast of New England receives only a small amount of the heat of the Gulf stream.

§ 17. *The Atlantic tidal wave.* The ocean, under the influence of astronomical forces, is acted upon in mass, and its waters rise in advancing or retreating waves, according to the position of the sun and moon, which are the positive agents in effecting these movements. By the rise and fall of the wave the detrital matter is borne forward in the direction of the advancing undulation. The great tidal wave of the Atlantic moves from south to north along the eastern coast of the United States, impinging upon its irregular shore, by which the inward terminus of the wave is retarded. It flows up the bays and harbors, encounters the river currents, which it retards, and in consequence of which the heavier portions of their burdens are deposited. In its onward progress to the north it is deflected to the east by the subaqueous banks. The easterly direction is continued till it passes the eastern soundings of Newfoundland; it then resumes its northerly course. To the interposition of an irregular coast, causing a retardation of the free forward movement of the advancing wave, great offshore and bank deposits are due; the latter of which are well known as the George's and Newfoundland banks, Sable island, &c.

The line of soundings and the sand deposits lie in the general tide wave which washes the shore of the continent, but which acquires a maximum accumulation in the banks which have just been spoken of. These great deposits are due mainly to conflicting currents, which are here met with, particularly the confluent tide wave of the Atlantic with the divergent wave of the American coast.

§ 18. Local and specific deposits belong to the same agency as that producing the great cumulative masses of George's, Newfoundland banks, and Sable island, &c. The tides, as they are usually understood, or as they are known to the common observer, exert a constructive influence upon the materials conveyed to them by river currents. The flood tide, advancing into a bay, sound, or estuary, bears onward its burden as has been already described. It deposits it along the shore in consequence of its conflict with the bottom and irregular sides of the projecting land, forming thereby a sandy, ridgy border of greater or less extent, according to the amount of the detrital matter it has received. The outward flow, or ebb tide, distributes the materials in a more central track, but is less effective than the flood tide: it renders the deeper parts of the bay more shoal, as it partially gathers the detritus from the sloping shores under the convex crest of the retiring wave in the deeper channels. Aided by the river current, detritus and floating bodies are moved far out to sea. If the cumulative process were confined to the bay or estuary, the bottoms would be raised much more rapidly than at present. One of the effects of the tide wave is to drive across the mouths of the deep coast indentations and bars of sand. In process of time these bars rise to the surface, and inclose a bay, producing thereby a lagoon, which becomes first brackish, and afterwards fresh water. This fact has an important bearing in geological reasoning, as it is in these reclaimed areas that we find oceanic or pelagic shells, estuary, and fresh water, and land remains superimposed upon one another. The breaking down of the bar by powerful waves may convert an inland lake to a bay of fresh or salt water,

which in time will be peopled with marine inhabitants, forming a complication of deposits of the most interesting character.

§ 19. *Wind Wave.* The sea, as well as fresh water lakes, are raised into waves by winds. The movement of such waves will exert a constructive action upon the coast close inshore. The obvious effect of wind waves is to raise the sandy deposits in a ridge, sloping more rapidly upon the land than upon the sea side. This process often cuts off a bay from the sea, the ridge running parallel to the main shore from two projecting points. On the land side there may be a lagoon and a marsh, which in due time will be filled up by aquative plants intermixed with soil or sand. The parallel roads and ridges traversing a country in the axis of its valleys, are often wind ridges, which mark the former shores of a lake or of an arm of the sea. These may be hundreds of feet above the sea level. They do not indicate a depression of the ocean level, but that the land has been raised in successive stages. Under favorable circumstances the wind wave pushes onward the sand detritus upon the land. The march inland devastates the soil, and spreads over it barrenness and sterility. The inland sands form the dunes. They may be arrested by a vegetation which delights in an arenaceous soil, such as the beach grass (Calamagrostis arenaria), or some of the species of pine.

A gentle breath of wind produces a ridged surface upon the sandy bottom. Waves of great strength destroy this rippled surface. The ripple mark will be formed in a vessel of water charged with earthy matter. The slightest agitation, as walking across the floor, will be sufficient to arrange the sediment like ripple marks upon a beach. Raised beaches are often the joint effect of the tidal and wind wave, especially where the direction of the wind is constant. The transporting power of flood tide is not obliterated by strong contrary winds, as the north-east winds upon our coast and the advancing northerly tide wave fully show.

A constructive action is not the uniform result of the tide wave; its action is often destructive. Sea bluffs are broken

down, and the soil is washed away, and carried to other points upon the coast. Portions of Long island, Martha's Vineyard, are undergoing changes of this kind. Points of land where fortifications and lighthouses have been built, have often been undermined by sea action. The sea encroaches on the land. But the constructive action has greatly exceeded the destructive on our own coast.

§ 20. Ice and semifluid ice is an instrument of change which should be noticed in this connection. Water congeals, and remains so the whole of the year, upon mountains which rise above 15,000 feet above the sea under the equator, and at still lower levels at points north or south of it. In consequence of this, there are vast accumulations of snow and ice upon the tops and in the high valleys of many mountains. These beds of snow and ice are called glaciers. This ice, as it approaches the lower parts of the mountain, softens, and becomes movable upon the inclined plane upon which it rests. The glaciers freeze, however, during the night, and become stationary; but becoming softened, or partially thawed, during the day, they again move on at a certain rate. The middle moves faster than the sides. The glaciers are now regarded as instruments of change upon the rocks over which they move. The position of these glaciers is such that they receive all the rocks and debris of the mountains where they are formed. They exist more or less throughout their icy beds, and hence it often happens that rocks stand out from their inferior surfaces. Owing to this circumstance, the glacier, as it moves, forces these rocks over the rocks in place beneath: they are therefore abraded and loosened, and the melted ice, as it flows away, is charged with mud, which is merely the matter worn off from the rocks. The glaciers then work mechanically, and with great power; and thus they aid in the process of leveling the mountains and filling up the valleys at their base. Glaciers, when they reach the sea in high latitudes, carry directly the abraded matter to the ocean. Glaciers in high latitudes jut over the sea, and the sea edge being left unsupported, break off from the main

mass, and fall into the ocean. These are icebergs. They then drift away, and are carried by currents out to sea, and often reach, in the northern hemisphere, the latitude of the Azores. On their march, they melt and distribute their burthens of earth and rock over the ocean's bottom. It is maintained by eminent geologists, that glaciers were formerly far more extensive than now, and hence there was a period which deserved the name of glacial period.

§ 21. The general tendency of the operation of water, as described in the foregoing paragraphs, is to form accumulations on the lines and planes of flow, or a little outside of them; which, beginning upon the mountain tops, terminate in the broad ocean rivers. The coarsest matter is left near the summits, and the finest is carried to the bottoms of the ocean rivers. Another belt of coarse materials is along the ocean shore and margins of lakes. These materials are mostly hard and siliceous, and resist change a long time; but they become pebbles and sand by attrition. These form the conglomerates.* Farther out from land there is a mixture of fine silex and clay; and still farther, in the flow of ocean rivers and currents we find suspended the finest particles of carbonate of lime and alumine still mixed with the finest sands. In this distribution of materials, we learn that three contemporaneous deposits may go on, the siliceous, the conglomerate and sandstone, the clay slates and shales, and the limestone rocks. As marine animals and plants occupy different stations, some living in shallow and others in deep water, it is plain that these rocks which are being deposited, will very likely contain the remains of animals of different species, though of contemporaneous formation. The nature of the bottom, too, influences the law of distribution of animals, as well as plants. Hence, at the same depth, and under other circumstances which are equal, a sandy shore is

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* Conglomerates are cemented beds of pebbles formed in water. Pudding stones are cemented pebbles formed above water upon dry land, by percolation of water holding carbonate of lime and silex in solution. So the travertin and tufa are formed above water.

peopled with different species than the soft muddy ones. All these facts are important in geological reasoning.

From the foregoing we may also learn the influence of water as a formative agent. It moulds and forms, as it were, all the coarse and fine materials which are abraded from preexisting rocks. It spreads them out upon bottoms, and deposits layer after layer. We may have a glimpse also of the time required to form rocks. Only a few thin layers, like paper, are deposited annually; and it is probably a rare occurrence, that streams are so loaded with mud that living shell fish are buried beneath it.

§ 22. The foregoing details of the distributive, as well as constructive agencies of river and oceanic waves and currents, will be more complete by a relation of the distribution of an animal life upon the ocean bed. The profound depths of the ocean are tenantless wastes, except for the dead, who have here found their resting places, where no wind or wave can move them, or bring up their sacred relics to light, and cast them once more upon a troubled shore. Along shore, in the reach of soundings, the waves distribute their burdens in ridges. These ridges are also in the main desert lands; but the valleys being protected by the ridges, teem with activity and life. Upon the slopes the rounded and worn materials are cast together with the remains of the exuvia of organic life, which have been cast off. The deeper valleys are suited to one class, while the shallower portions are sought by others. From shallow water, or the high water mark, to a depth of thirty fathoms, forms the main range in depth of marine animal life. Vegetable life, however, rises up from greater depths. Thus the gigantic sea weed of the Falkland islands rises from a depth of 300 feet. The sea bottom, therefore, like the earth's surface, presents all the variations of contour which are necessary to give life the widest exhibitions of form and character. The profound depths, like the snow-tops of the Andes and Himalaya, are dreadful wastes, devoid of life; the one awful from its profound solitude, the other fearful from the howling blasts which sweep their towering tops.

§ 23. The coast of the United States is flanked within soundings by an arenaceous deposit, arranged in the manner already described. The shore deposits are more thoroughly arenaceous than the more distant depths occupied by the valleys. Here the formation is more muddy, and partakes of an argillaceous character; while it is highly probable that farther from land the calcareous matter will be found. The West Indian archipelago may well be regarded as the repository of the calcareous formations. Here, aided by the incessant toil of the coralline animals, a limestone bed or rock is in the progress of formation, equal in extent to the Onondaga limestone of New York, and like that abounding in branched corals and massive madrepores, fragments of shells, together with the perfect animal forms which abound in the Carribean sea. This formation becomes the conservatory of the constructive works of man, as well as the burial place of his remains. Guadaloupe has furnished an instance verifying this assertion, by the discovery of a human skeleton nearly perfect in its parts. No sea is so richly freighted with the remains of animal life from the highest to the lowest—from man to the polyp. An entire record of human life, since the day the Carribee set his foot upon these islands, is treasured up in the archives of its deposits. Every layer is a leaf bearing the impress of the past; and the medals strewed profusely upon its bottom tell of the strange vicissitudes of a lost continent, whose existence is proclaimed by the crests of Cuba and the volcanic peaks of the lesser Antilles.

§ 24. The complexity which is created in geological researches by the contemporaneous formations, may well create a hesitancy in pronouncing upon the age of a given deposit. Looking upon the present as a type of the past, we see in the arenaceous shores of America the exterior muddy deposits, which may be regarded as argillaceous, and the coralline formations far from its coasts, whose rocky nature is completed by the cementing agency of calcareous matter in solution and suspension. Three contemporaneous formations of vast extent and importance, and which, being judged of by their lithological

and fossiliferous characters, would be regarded as formations of different eras. Taking it then as a type of the past, we may well doubt the correctness of many of the geological data which have formed the foundation of our reasoning. Tidal waves, normal oceanic currents, and river currents, with their burdens of detritus, have ever exerted their powerful agency in distributing the waste materials of continents, and in constructing the fossiliferous mountains of the globe. Conglomerates, coarse and fine sandstones, if we regard the foregoing facts, may always be considered as shore deposits, and argillaceous and calcareous rocks as pelagic formations; especially may we recognize in most of the calcareous rocks formations similar to the recent beds in the Pacific and West Indian islands.

§ 25. The systems of relief of the North American continent are not as yet well determined. The mountain ranges, however, pursue a northerly and north-easterly directions, by which it appears that the force which raised the continent acted in those directions, or that this force preponderated over all the forces acting in other directions. On the Atlantic coast it is north-easterly, or parallel with the coast line; on the Pacific coast it is northerly, and parallel with the Pacific coast line.

Considered as water sheds, the ranges of the United States may be reduced to five: 1. The Appalachian, which is parallel to the Atlantic coast; 2. The Green mountain range, which runs north, or six or seven degrees east of north; 3. The Rocky Mountain range, which, according to the best maps, is also directed to the north; 4. The Pacific coast ranges, which are north; 5. The Lawrentine range, which pursues an easterly and westerly course. These chains of mountains are often flanked by parallel ones, which attain at many points greater heights; yet they are evidently subordinate to them, since they are broken through by the water courses, and are not coextensive with them in length. Thus the Taconic range flanks the Green mountain on the west in western Massachusetts and Vermont; yet Graylock of the former rises nearly 3600 feet above tide, and the latter only 2500. Black mountain flanks the Blue

ridge in North Carolina: the former attains a height of 6200 feet, while the pinnacles of the latter are about 5000 feet only.

The slopes of the water shed of the Appalachian range is to the southeast, or to the Atlantic, on the east side; but to the northwest on the west side, or towards the main trunk of drainage, the Ohio river. But it has also a southern slope, by which it furnishes a drainage into the gulf of Mexico.

§ 26. The Appalachian range begins in the northern part of Alabama, and terminates with the valley of the Mohawk. The culminating point is the Black mountain in North Carolina; and the culminating ridges extend north from Black mountain to Grandfather mountain, by Table rock in Burke county, North Carolina. Here are five close-pressed parallel ridges, of which the Blue ridge is a subordinate to them all; but when traced in either direction it becomes the main and principal range of upheaval, and forms withal the crest which divides the Gulf system of waters from the Atlantic system. The Green mountain range runs north six or seven degrees east. It is regarded by President Hitchcock as the Meridional system of Massachusetts and Vermont. It begins upon the Sound, and extends into Canada East. The two principal rivers which drain their slopes are the Hudson and Connecticut, whose courses are parallel with each other. The Taconic range is separated by a well defined valley from the Hoosic range. The latter is the eastern rim of the rocks of the Taconic system, and which have suffered many dislocations since their deposition. The fractures are parallel to the main range. Igneous injections are almost unknown in that part of the Taconic system which lies north of the Highlands and south of Rutland, Vermont. The Hudson river runs upon a line of fracture which extends from New York to Montmorenci in Canada East, lake Champlain being a wider and deeper fissure than that along which the river flows.

The Atlantic slope bordering the ocean is exceedingly gentle, indeed: the country is nearly flat until we encounter the first low granitic ridge, which creates a line of falls in all the

southern rivers, viz: the Rappahannock at Fredericksburg, James river at Richmond, the Roanoke at Weldon, the Tau at Rocky Mount, the Neuse six miles east of Raleigh, the Cape Fear near Haywood in Chatham county, or at the falls of the Buckhorn. Above the falls the rivers are more rapid, but their ascent to the base of the Blue ridge is still gentle, though rapid at many places. At the base of the crest of the Blue ridge their height above the ocean rarely exceeds 500 feet. From this point up the ascent on the east side is exceeding rapid for five miles. On the west side the slope is again gentle. It appears, therefore, that the slope is on the west side towards the Mississippi valley, while the counter slope is on the east, and contrary to that which prevails in Pennsylvania and New York.

A remarkable feature in the Atlantic plain, forming part of the eastern slope of the Appalachian range, is the country of the Pine barrens. These are sandy plains, undulating like a sea bottom, and clothed with the long-leaved pine. Although of considerable extent, and traversed by rivers and streams, the sand, though a marine formation, furnishes no fossils, except silicified wood, which is derived from the triassic beds of Deep and Dan rivers. These monotonous barrens are analogous to the prairie lands of the west. Towards the north the Atlantic slope becomes less sandy, and its vegetation is in accordance with a gradual change in climate and soil. To the south this plain extends westward and southward, and connects itself with the Mississippian, by turning around the southern points of the Appalachian chain in the north parts of Georgia and Alabama.

§ 27. The Mississippi flows upon a low ridge or anticlinal axis. The country westward swells and rises gently, and finally attains, at the base of the Rocky mountains, an elevation of about 5000 feet at the South pass. A pass lower by 2000 feet has been discovered by Governor Stephens. The culminating points of the Rocky mountains are near Fremont's peak and the three Tetons, as here the Colorado, the Missouri, and the Columbia take their origin. The Rocky mountains

are belted by a sandy desert some 400 or 500 miles wide, which is prolonged northward to the mouth of the McKenzie river, a distance of 1500 miles.

The coast range of the Pacific, and the Sierra Nevada, are parallel chains, and separated by the valley of San Joachim and San Francisco. These ranges, prolonged into Oregon, are succeeded by the Cascade mountains. These three ranges frequently rise above the line of perpetual snow. The outer range is only 380 miles from the Pacific ocean. Considered as continental ranges, their slope is towards the Atlantic, and the counter slope to the Pacific. They are in the ratio of two to one. The great valley and its slopes drained by the Mississippi, and its thirty-four navigable rivers, contain an area of 3,245,000 square miles. The Mississippi trunk is navigable to the falls of St. Anthony, and the Missouri high up the waters of the Yellow Stone.

§ 28. The Lawrentine chain is comparatively low, not exceeding 2500 feet. It is but little known. It divides the waters of the St. Lawrence, the Mississippi, and the rivers of the British territories. The chain varies but a few degrees from east to west.

A small mountainous tract lies north of the Mohawk, between the St. Lawrence and Lake Champlain. The four distinct ranges by which this tract is traversed are parallel with each other. Their axes are directed to the north-east. The main chain rises at Little Falls, and pursuing a north-east course, terminates abruptly at Trembleau point on lake Champlain. The culminating point of this range is mount Marcy. This mountain is the center of the Adirondack group, and rises to the height of 5467 feet. From this group the drainage is composed of the Ausable, Saranac, Racket, Black, and the branches of the Hudson river. The lakes situated upon the table land, and from which these rivers rise, are from 1500 to 1800 feet. This level is about the same as that of Connecticut lake, and not greatly inferior to the lakes which give origin to the Mississippi.

How do we know that the present valleys and mountains were not coeval with the foundations of the earth, or that many of them have been formed since it was inhabited? This fact is determined, like all other facts, by observation. Though we do not witness their formation, still our observations are not the less certain and true. We learn first what rocks compose the mountain and its valley—the arrangements of their strata, and the relative position of the principal and subordinate masses. We examine its cliffs, its fractures, and veins. With equal care we examine the valley, and compare its formations with those of the mountain. We find they agree. If a traveler should find by the roadside the parts of a broken walking stick, how would he know that they were parts of one stick? He would find that the pieces were the same kind of wood, that they were colored and polished alike, and that the ends of the fractured parts fitted each other. So, in the same way, the strata of the mountain are the same as the valley, and the fractured ends, if brought together, would fit each other. But the cliffs are a thousand feet above the valley, and their present position is incompatible with the mode of formation of all sedimentary rocks. They are not in the position required by sediments, hence a part has been broken from the mass and elevated, and now forms the mountain mass, while parts of it still form the valley below; and the rocks themselves still retain the marks of the operating force in their curved and contorted beds. They too are the repositories of fossil remains of the same kinds. Long since the time they formed the ocean bed, they were raised from the depth of the sea, and their fractures and dislocations attest the action of forces which elevated them to the positions they now occupy.

§ 29. *River systems.* The machinery by which the earth is watered is extremely simple. The atmosphere, set in motion by heat, is the carrier, and mountains and hills the condensers of moisture. The rivers receive their supply of water from an infinitude of streams flowing from the sides of mountain chains. The simple process of condensation of the moisture of clouds

and winds keeps a perpetual flow from the mountain to the sea; and the wind current, in passing over the ocean, loads itself with vapor, which is ready to fall in mist and rain upon surfaces cooler than itself.

In these simple facts we find an explanation of the origin of the river systems of this country, and of all countries. The Appalachian, the Rocky Mountain, and Pacific Coast chains, with their numerous spurs and branches stretching from the Gulf to the British possessions, form an immense condensing surface, sufficient to irrigate and fertilize 3,000,000 of square miles. It is a singular fact, that the United States is watered by rivers which rise in its own borders. The crest of the great water shed dividing the river systems which flow to the north and south, formed by the Lawrentine chain, rises not far from the boundary between the British and American territories. The rivers of the Atlantic slope are short, and comparatively small. The Potomac, the Delaware, and Susquehannah spread out into wide and deep bays. This results from the porous nature of the tertiary deposits which belt the coast. The Hudson and other northern rivers are rock-bound, and hence their bays are narrow and inconsiderable. The tide flows up the Hudson 160 miles from the ocean. It cuts the primitive rocks of the Highlands and some of its branches, and flows over the lower silurian formation beyond.

The Mississippian is the great river system of the United States. It is second only to the Amazonian. The Missouri is the great trunk of this system. It rises high up in the Rocky Mountain chain. The innumerable streams draining the eastern slope, converge and form four great rivers, which, uniting in the distant plain, form the Missouri. This unites with the Mississippi twenty-five miles above St. Louis. Measuring its windings, it has already reached a point 1500 miles from its source, and its journey is only half finished. Its current is rapid, and it carries mud and sand, derived from the soft cretaceous and tertiary formation through which it has flowed. A particle of water, starting from the steep sides of the Rocky mountains,

reaches St. Louis in about twenty-five days. But the most interesting fact which the Mississippian current reveals to us is contained in the sediment. The last resting place of this matter was in a cretaceous sea. Where they then came from, and how many transportations they had undergone, will never be revealed. In our geological reasoning they are destined to form the most modern deposits. They have undoubtedly passed through all the historical periods since aqueous deposits began to be formed. The particles are as old as the foundations of the earth, but the formations of which they are destined to form a part, are becoming the newest. They have been associated with the oldest organic beings, but they are now brought in contact with the most recent—with the people of the present age. The recent is made of particles derived from every known period. The water of the Mississippi is clear compared with the Missouri. Above its confluence with the latter it has a long and gentle descent. But its progress, in one respect, differs from that of the Missouri: it passes through many lakes, a fact which is unknown upon the course of the latter river.

The Mississippian system, unlike the Atlantic system of drainage, has two slopes, an eastern and western. The former, however, has more than twice the area of the latter. They unite, and form the basin of the Mississippi.

Above New Orleans, where all the great trunks of this system of waters flow in one channel, the quantity of water is immense. According to the most reliable calculations relative to the quantity which this river discharges into the ocean annually, it amounts to 14,883,360,636,880 cubic feet. The amount of sediment transported to the ocean by the Mississippi is 28,188,083,892 cubic feet. This sediment is sufficient to form an annual deposit one mile square, and 1000 feet thick. As the delta of this river contains 13,000 square miles, and as the sediments of the delta are at least 1056 feet thick, it is evident that the time required to accumulate so much material must have been greatly protracted. Fourteen thousand years has been stated as the result of the best observation which has hith-

erto been made. But the finest of the sediment probably passes over the river bar, and may be carried far from the delta by oceanic currents. The actual time, then, consumed in the formation of the delta is greater than the calculated.

What takes place by the instrumentality of the Mississippi, takes place in the same mode by all rivers. As the winds are the carriers of water, so the rivers are the carriers of sediments. By the combined machinery of wind and water all the sedimentary rocks are formed. Water, acting upon these plastic materials, spreads them evenly upon deltas and over wide areas upon the ocean's bottom. Here, subjected to a great pressure, they become consolidated into rock.

§ 30. *Winds, as the distributive agents of heat and moisture.* The geological agency of the wind is modified by its direction. The trade wind of the Gulf furnishes a supply of water for the western slope of the Appalachian chain, and the northeast wind of the Atlantic brings a supply for the New England and Middle states. The mountains of Oregon condense the moisture of the northwest winds which have passed over the Pacific. To the Eastern states the same wind is dry and cold, having been robbed of its moisture, as well as cooled, by the highlands over which it has passed. A continent is indebted to the agency of winds for the supply of water, both for its vegetation and that which is required to feed its rivers and streams. They dry the earth's surface when wet. Sixty per cent of the rain which falls in the valley of the Ohio, is restored directly to the atmosphere, or is taken up by vegetables. The southwestern winds are warm and damp from having passed over the Mexican gulf. This great body of water is of the utmost importance to the well being of the Appalachian slopes and valleys, imparting moisture and a subdued temperature where in its absence it would be dry and hot.

§ 31. The earth's surface is acted upon mainly, as I have already stated, by two distinct and diverse agencies, fire and water: the former, by its well known properties, which are manifested in the simple expansion and fusion of matter; the

latter, by its transporting power, and by the aid of frosts in breaking up the strata and disintegrating the exposed surfaces. The entire operation may be summed up in two processes, one of which degrades the more elevated parts of the earth's surface, and the other fills up the depressed portions. Fire or heat operates in four ways: 1. In the elevation of areas by the application of expansive forces beneath the earth's crust, by which it is raised up in mass. 2. By the transference of fused matter from the interior to the surface, and which it overflows, and thereby makes an additional thickness to the visible strata. The addition being transferred from the interior to the exterior, may be in the form of melted matter, semifluid matter, or in the form of mud, or in pulverulent matter, in the condition of ashes and semifused mass ejected from the craters of volcanoes. 3. In consequence of the loss of matter thus thrown out from the interior, areas of subsidence are formed, and the superficial strata are engulfed suddenly, or else slowly subside and sink below their former levels. 4. Areas are elevated or depressed by the simple expansion of strata by heat and their contraction by cold.

The force generated by heat is proportionate to its intensity. It pervades, in a limited degree, the zones of rock immediately beneath the earth's surface. This is proved by its increase downward from the limit of solar influence, which is a point of no variation for the year. The ratio of increase for this country is one degree of Fahrenheit for every fifty-five or sixty feet, and for Europe one degree for every forty-five or fifty feet. These facts point to a source of heat in the earth's interior. This view is supported by the overflow of immense quantities of incandescent and melted matter from volcanic vents. Like all other bodies, rocks are expanded by heat and contracted by cold, and these changes in volume are connected both with changes of level in the earth's crust and in its disruption, or the forcible separation of continuous strata, and the formation of intervening fissures. In the simple expansion of rocks by heat, and their subsequent contraction by cold, we have an

element which is competent to explain many phenomena connected with changes of the earth's crust.

Rocks are fused in the interior of the earth's crust, and in that state may rise to the surface. The fused rock often overflows the brim of craters, and flowing down the mountain sides, breaks and vitrifies the rocks over which it flows, and fills the hollows in its line of march. So, also, fused matter may rise in the fissure formed by disruption, and after reaching the surface flow like a lava current over its edge, or force itself between the layers of a sedimentary rock.

Internal heat must be regarded as an arrangement which conduces to the well being of the earth's inhabitants. It no doubt ameliorates the cold, and sustains that degree of temperature which is best fitted to the organic and structural conditions of living beings.

§ 32. *Time is an element in geological dynamics.* It is measured by forces whose operations we may witness. In the estimation of time we follow two methods, the results of which agree. The first method, we estimate the rate at which deposits accumulate in the present seas. The measuring line which we thus obtain is applied to the past. The second method is the reverse of the first. We estimate the amount of matter in the sedimentary rocks of all periods. This matter is composed of the waste of former continents and former mountain ranges. The sediments of each period are immense; and immense as our present mountain systems may be, still the sediments and wastes which have accumulated since animals and plants have lived, are sufficient to compose many such mountain systems as now exist. Life materially aids us in making our computations. It determines the slow rate of the accumulations of which we have spoken. We are not to presume that the Prime Mover, the great Efficient Cause, has hastened events because he has the power. Events are preceded by preparatory steps, and time and events develop themselves in stages and periods. Like the planets in their orbits, they may be accelerated in motion for a moment, and

the forces may act more intensely as they pass disturbing bodies, still the sum of the results in long periods are the same.

In geology time is only relative. It can not be absolute, or at least absolute time can be reckoned only for those changes which have taken place in the historical period. But absolute time is diminutive compared with relative or geologic time.

§ 33. It has been shown that sediments of the same age occupy positions which are determined in part by their size and weight, or the form of their particles. The large and heavy particles are deposited early, while the fine are transported far out in the ocean. The sediments are distinguishable by the forms of their particles, their peculiar arrangement, or by the presence of fossils. Attrition rounds the salient angles, though it often happens that particles are consolidated while they are still angular. They have a foliated arrangement, being superimposed upon one another. This foliation has received the technical name of stratification. Stratification is manifested by folia of different kinds of matter, as sand, mica, and talc, or by folia of different colors. An amorphous mass of materials, as cart loads of sand, gravel, and stones, become stratified by the percolation of water when thrown down into heaps. Lamination closely resembles stratification: it is the separation of a mass into thick or thin layers by an imperfect or unfinished crystalization. Gneiss, mica slate, and talcose slate, are examples of lamination. Where the planes of separation are indistinct, the term sublaminated may be employed. It is proper to distinguish these two forms of the separation of the parts of rocks. The lamination of gneiss, mica slate, &c., can not be regarded as a true stratification, as the arrangement of their parts is not due to the same causes. There is no evidence that the mica or feldspar planes in gneiss, or the mica and quartz planes in mica slate, were the result of a sedimentary process. Where heat has been sufficiently powerful to fuse pebbles, it must also perfectly destroy the stratification, and the present so-called stratification of gneiss must be due to the heat and fusion the mass has suffered. I would

therefore prefer the adoption of the term *lamination* to be applied to the rocks designated, rather than to continue and extend the use of the term *stratification*. I would restrict this to sediments, or transported matter, which have been subjected to the action of water.

§ 34. We may observe frequently a condition in massive and stratified rocks which is not due to the conditions which existed at the time of their formation. In granite, for instance, where it is exposed to disintegrating agencies, there may be observed a separation of its mass into laminæ, or into thick tabular masses, simulating a laminated rock. When this condition is examined it may be referred to a molecular force, or to a concretionary movement of its particles. The separation takes place in parallel planes, but they are usually curvilinear. Sedimentary rocks undergo changes from the operation of the same forces; the original planes of stratification are obliterated and the new planes which are formed are concentric, and arranged around a nucleus. Another change takes place in rocks whose particles are bathed in water. Clays, and clay slates, and limestones of all ages, contain rounded masses which are known as septaria, clay stones, or concretions, nodules, &c. This is a most interesting change. These bodies may be either purely siliceous, or they may be calcareo-aluminous. The siliceous concretions are abundant in the carboniferous limestones of Missouri near St. Louis: the flint nodules and layers in chalk is another example of the kind. The slates furnish the calcareo-aluminous bodies, which in clays are known as claystones. They are abundant in most clay beds or marls of all ages; and those of the slates which are known as septaria, differing from the former by their septa, are formed of crystalline limestone, barytes or strontian. We are obliged in all these instances to recognize a force, by virtue of which the molecules are really transferred to central points, where, by constant accumulation, they form a nodule, or septaria, or concretion. This force is operative at all times, and upon all rocks. Molecules are never at rest until they have acquired a

symmetrical arrangement. Concretions and nodules are symmetrical bodies. The parallel planes of the rhombic forms so common in limestones and slaty rocks are due to this force. The jointed structure admits of the same explanation.

§ 35. *Composition of the earth's crust.* The mineral kingdom is composed of a large number of distinct species of substances, the knowledge of which is highly important. The composition, however, of the rocks or masses is represented by an extremely small number of simple minerals, which are repeated over and over again in the layers of the rocks. The rocks are either mechanical mixtures of a few simple minerals, or they are made up of a single simple or homogenous mineral by itself. Granite, gneiss, sandstones, and conglomerates, are examples of the former; and limestone, gypsum, serpentine, and hornblende, of the latter. The elementary bodies are extremely rare in nature, or in the mineral kingdom. Sulphur is common in volcanic districts, but is a product of decomposition. Carbon, nearly pure, exists under the form of anthracite. The metals, gold, silver, copper, and mercury, may be said to be of frequent occurrence, but can not be claimed as component parts of the masses geologically considered.

The minerals which predominate in the earth's crust are the siliceous, aluminous, and calcareous. Silica, as a constituent part of the rocks, occurs under two forms: the first and most obvious and common is quartz, as it exists in flint, white sand, or an aggregation of sand in the form and condition of sandstone; the second is an acid, and is combined with one or more bases, and forms those bodies which are called silicates: feldspar, hornblende, mica, and pyroxene are examples. Some rocks contain examples of both forms, as granite, where it is in the first form as particles of quartz, and in the second as silicates in the feldspar and mica. The aluminous minerals are represented by common clay, as it everywhere occurs, or by slates which are consolidated by pressure, or baked clay still more consolidated and changed by heat. These examples, however, are not those of pure alumine; they are mixtures of

silicates and of fine and impalpable sands. Their purity or approach to alumine is indicated by their whiteness.

Limestone is composed of carbonic acid and lime. As marble, it is nearly pure. When acid is poured on limestone it effervesces or boils by the escape of carbonic acid. Lime is also found combined with sulphuric acid, when it forms gypsum. It may be distinguished from the carbonate by its softness, its fusibility, and the absence of effervescence in the presence of acids.

The sediments are mixtures of the silicates, sand or quartz, in fine or coarse grains, pebbles, clays, sandy clays, limestones, or sandy and aluminous limestones. These mixtures, however, never form chronological successions; neither do they occur in modes or ways by which their lithological properties may be used as characteristics of age or place. To say that a rock is limestone, sandstone, or slate, conveys no idea of its place. It is a mineralogical fact which has some importance.

Among the chemical and mechanical mixtures iron is rarely absent. Its presence is usually indicated by red and brown colors, which it imparts to the mixtures containing it. The red and brown sandstones are stained with it. Of the simple bodies, however, oxygen must be regarded as the most general, and most widely diffused in the mineral kingdom. In a state of purity it is aeriform. Its properties are better known to us in its mixture with nitrogen, forming the atmosphere. Very few substances are known which do not contain it. The iron which has just been referred to, is a compound of iron and oxygen, or it is an oxide of iron. Sulphuric acid, which forms a part of gypsum, is a combination of sulphur and oxygen; and carbonic acid a combination of pure carbon and oxygen; quartz or flint is silicon and oxygen; and quick lime is calcium and oxygen.

§ 36. It is a point upon which all geologists agree, that the earth's crust is composed of rocks which have been formed at different periods. Both the rocks and periods being numerous, it is important they should be arranged into groups or classes,

according to characteristics which belong and are common to each of the respective groups or classes. Attempts were made at an early day to construct such an arrangement of rocks as would meet the ends in view. These attempts embody the views of the prevailing systems of geology, and the nomenclature employed to express the generalizations of the authors have been found both defective, as well as expressive of fundamental errors. The more recent attempts of classifiers have been confined mainly to the use of terms which express facts. The rejection of the terms *primitive*, *transition*, and *secondary*, and perhaps *tertiary*, seems to be acceded to on the ground that they express a theory which is untenable in the light of modern discoveries; although the names might continue to be employed without endangering the interests of the science, provided those names were used simply as names, without regard to the theoretical views of the authors who first used them. It is an interesting fact, that the terms transition, secondary, and tertiary, the three periods to which they have been applied, stand forth the prominent *triads* of geologic time. It is no less certain that primitive or primary express also truly in the main the fact they were originally designed to convey. The nomenclatures of all the schemes of arrangement are objectionable, inasmuch as they are not consistent with the demands of science. The slight modifications which I have proposed in nomenclature it is hoped will not be regarded as an unwarrantable innovation, as they are the expression of admitted facts. Still there is a want of unity in the names, which may be corrected hereafter as discoveries are made. The systems into which the hydroplastic rocks are divided are arranged chronologically, but the names which have been given to these systems are by no means chronological. But by dividing these systems into three groups, we may express approximately their chronology in the terms palæozoic, mesozoic, and kainozoic. At present the most fashionable, and perhaps too the most useful names of systems, are taken from localities where those systems are well developed, of which we have an eminent example in the word

silurian. So long as this name for a system of rocks is retained, so long will its example find imitators.

CLASSIFICATION.

		Stratified.
III. HYDROPLASTIC, ...	c. *Kainozoic*, ..	Alluvial and drift, Pleistocene, Pliocene, Meiocene, Eocene.
	b. *Mesozoic*, ..	Cretaceous, Lias and Oolite, Trias.
	a. *Palæozoic*, ..	Permian, Carboniferous, Devonian, Silurian, Taconic.
II. PYROPLASTIC, ...	b. *Sub ærial*, ..	Lavas, Tufa, or Volcanic Products.
	a. *Sub marine*,	Greenstone, Porphyry, Basalt, Trap.
I. PYROCRYSTALLINE,	b. *Laminated*, .	Gneiss, Mica, Slate, Hornblende, Talcose Slate, &c. Laminated Limestone, Laminated Serpentine.
	a. *Massive*, ...	Granite Sienite, Hypenthene Rock, Pyrocrystalline, Limestone, Serpentine, Rensselaerite, Octahedral Iron Ore.

In the foregoing arrangement, the rocks which have been called *metamorphic* and *azoic* by several eminent writers, have not been recognized as classes, or even as subdivisions of sections, inasmuch as they can have no special peculiarities which make them applicable for such purposes. Metamorphism occurs, or may occur, in all the series of rocks from the earliest to the latest sediments. It is true, the term metamorphic has been confined to gneiss, mica slate, hornblende, talcose slate, &c.; but its use is theoretical, and was thus applied on the hypothesis that those rocks are altered sediments, of which there is no evidence. The term *azoic* is still more objectionable: it presupposes that our observations have made certain that which from the nature of our evidence must ever remain doubtful. There is no doubt but that granite, gneiss, mica slate, &c., are azoic, but no one would think it proper to apply it to those rocks.

§ 37. *Structure of the massive pyrocrystalline rocks.* The peculiar mode in which these rocks became consolidated furnishes a clue to their essential structure. This is crystalline. They are not only composed of crystallized minerals, but they are crystalline in the mass. This statement is sustained by the fact that, in the quarry where large masses are raised, they split readily in certain directions: it is in fact a cleavage similar in form to that of a simple mineral. These directions or joints of cleavage are developed by the disintegration of the rock by atmospheric causes, the action being always more perceptible in the direction of the cleavage planes; they appear to separate spontaneously, and to extend deeply into the rock. The rock in this condition shows all the directions in which it may be split. The annexed cut (fig. 1) illustrates the

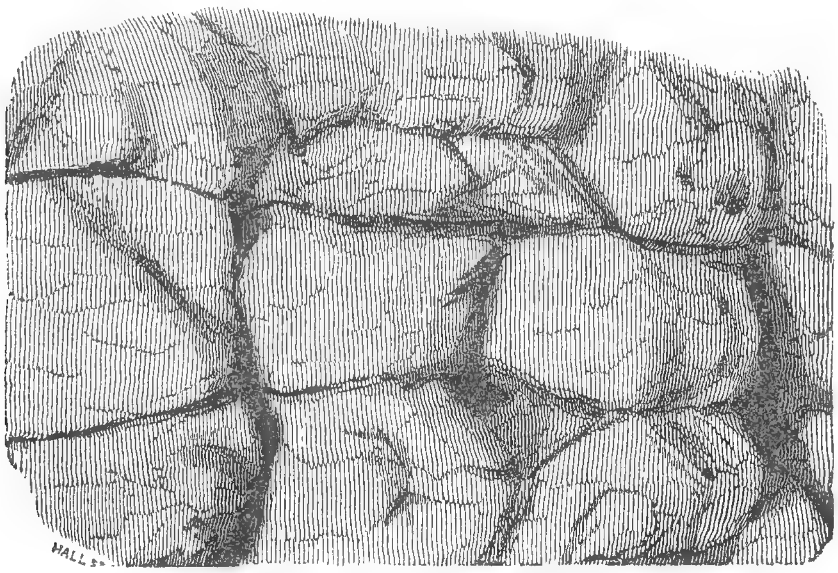

Fig. 1.

appearance of a mass undergoing the changes alluded to, and by which it is separated into angular parts. This result is not to be regarded as a lamination, inasmuch as lamination is the result of the arrangement of different minerals in parallel planes; and the ready splitting in the direction of those planes is due to the diminished cohesion between two different minerals in part, and in part, also, to diminished cohesion which always exists between the broad planes of crystals. The separation of the folia of mica or talc through their broader planes illustrates this fact.

§ 38. *Age of pyrocrystalline rocks.* The consolidation of the earth's crust resulted in the production of the pyrocrystalline rocks. If any part of the cooled pellicle thus formed remains, that would be the oldest rock. A pellicle must have been ultimately formed, and which still maintains its existence as a constituent part of it. From the manner in which the surface cools, the consolidated masses which successively form must lie in contact with the inferior surface of the first-formed pellicle. The thickness of the crust increases by additions below. This mode of consolidation differs materially from the increase of the crust by additions to the hydroplastic rocks, as these increase by new overlying deposits—a mode by which the newest or latest formed rocks are superior; while in the former the newer are beneath and the older above. When, however, the crust contracts fissures are produced, through which the still fluid matter finds its way to the surface, and may overflow the consolidated surface. The age of two rocks thus related is determined by very obvious facts. The rock intersected by fissures and filled with melted matter must be the oldest, and the intersecting mass the newest. Three, and even more masses may be thus related to each other. This mode of formation, as well as the indications of age, belong

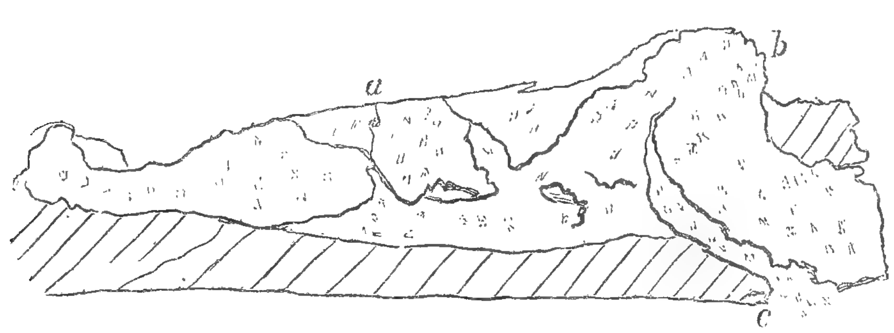

Fig. 2.

exclusively to this class of rocks, and in a series of adjacent beds we are to look for these peculiar relations, when it is desirable to determine which is the oldest and which the newest. The rule has a general application, as it is obvious that all intersecting masses of rock must be more recent than the intersected, whether the latter belongs to the oldest or newest

classes. Fig. 2 illustrates the mode of formation of the pyro-crystalline rocks, and the relative age of each mass.

§ 39. *The age of rocks deduced from the perfection of their crystalline state.* Assuming the former fluid condition of the earth by heat, and its present condition by the loss of it, it may be inferred that the greater intensity of heat produced fusions far more perfectly in the earlier than in the later periods. We may conceive, then, that the products of a perfect will differ in structure from those of an imperfect fusion. The former will be longer in cooling, and the particles of the mass will be in a more favorable condition to move freely and arrange themselves according to their respective affinities. The first products arising from the cooling of the earth's crust are the granites. These rocks are preeminently crystalline, and their perfect crystalline condition resulted from the former high temperature to which their masses were subjected when the whole earth was in a molten state. The products of the subsequent periods, when the earth's crust had materially cooled, are less crystalline. Thus granites in mass, the first products of cooling, are traversed by granitic veins which constitute a second stage in granitic productions. In periods still later trap dykes appear, and we find in their structure indications of a diminished fluidity by fusion: they are black granular or compact and homogeneous, or imperfect crystals of feldspar pervade the mass. The traps proper traverse the earlier and later rocks, and cut the more ancient granitic veins, but are themselves more rarely intersected by granitic veins; and even the massive greenstones are rarely, if ever, intersected by granitic veins. Granitic veins and beds, however, are products of all periods as late at least as the chalk; but their frequency is diminished in the ratio of a thousand to one, comparing the granitic with the cretaceous periods.

The foregoing considerations seem to favor the doctrine that the imperfect crystalline structure of the later igneous products is due in part to a diminished heat in the earth's crust. We have never seen a granitic vein intersect a trap dyke or a mass

of greenstone, although some granitic veins are newer than many veins and masses of trap.

The evidence of age, however, when deduced from structure alone can not be relied upon, only so far as it indicates a general diminution of temperature; traps and greenstones never forming those parts of the earth's crust which belong to the most ancient periods—the rocks of the most ancient periods being represented by granites and gneiss, whose structures are eminently crystalline.

Metallic veins—those of iron in northern New York, the auriferous quartz veins of Virginia and North Carolina—are traversed by dykes of trap or greenstone, and hence the former are older than the latter; and we have never seen the former traversing the latter, though in Derbyshire, England, metallic veins pass into them. Taking a general view of facts, however, as they are developed upon a large scale, we are inclined to adopt the opinion, that the prevalence of the intersecting dykes of trap are due to general and not to local causes, and that this cause will be found connected with the cooling of the earth's crust.

§ 40. *Special considerations respecting the elements of granite and its allied rocks.* Feldspar is the predominating element in all the massive pyrocrystalline rocks. It is a fusible compound, but the mass of rock in which it is so abundant may have been more fusible than feldspar by itself. The three principal kinds of feldspar, all of which are quite common in American granites, are composed of

	Prismatic Feldspar.	Albite.	Labradonite.
Silex,	65·40	70·7	53·70
Alumina,	18·60	19.8	29·90
Lime,	00·20	0·3	12·00
Potash,	15·70	0·0	0·90
Soda,	0·10	9·0	4·50

The presence of the alkalies and alkaline earths, while they promote as fluxes the fusion of the mass, materially contribute to its disintegration and decomposition. In consequence of

this last property, those rocks which have undoubtedly contributed to the formation of subsequent rocks, have had a great influence upon the character of the soil. The most important minerals associated with feldspars are hornblende and pyroxene. They are composed of

	Hornblende.	Pyroxene.
Silex,	46·26	54·08
Lime,	13·36	23·19
Magnesia,	19·33	11·49
Prot. ox. iron,	3·43	10·02
Ox. manganese,		0·61

The fusibility of hornblende and pyroxene is greater than feldspar, and as they are both associated with feldspar, they probably increase the fusibility of the compound. Hornblende and pyroxene rocks, however, decompose more slowly than feldspathic, in consequence of the absence of the alkalies. The latter rocks, however, contain in this country sulphuret of iron, and in consequence of its presence, these rocks undergo greater and more rapid changes than they would were they free from this substance. The feldspathic rocks, however, contain a much smaller proportion of sulphuret of iron; it is not associated so frequently with it. In the first group feldspar is the most important one of its compounds. In this country granites are the principal rocks of the group, especially since it seems to be proper to include under granites all the mixtures in which the three kinds of feldspar are found. In this country we are unable to add many of the minor compounds—those, for example, which are found in the ancient volcanic districts of Europe, as clintstone, porphyry, graystone, diallage rock, &c.

In certain compounds hornblende or pyroxene predominate, though feldspar is always present.

Epidote should be noticed in this connection. It is no uncommon fact to find this mineral where the change in a rock is comparatively slight. Chloritic slates, when acted upon but feebly by heat, almost always contain epidote. It may be massive or crystalline. Its peculiar yellowish green color

denotes the presence of this mineral. Its composition is represented below:

	Epidote.
Silex,	37·0
Alumina,	21·0
Lime,	15·0
Oxide of iron,	24·0
Manganese.	1·5

It is closely allied in composition to pyroxene.

GROUPS OF PYROCRYSTALLINE ROCKS.

§ 41. Three kinds of feldspar, the prismatic, albite, and labradorite, are frequently associated with hornblende and pyroxene. They form groups which belong to the later formed rocks, or to the pyroplastic rocks. Hornblende, taking the place of mica in granite, forms a compound which is called sienite, and it may be surmised that it is not the oldest kind of granite. The feldspars, when associated with hornblende and labradorite, constitute the greenstones, porphyries, basalt, and trap. These associations do not appear to have been formed at all in the earliest consolidations of the earth's crust.

§ 42. Feldspar, however, is not confined to the greenstones and basalts. We find it incorporated with many of the later formed pyroplastic rocks. Thus the claystones and clinkstones are compact rocks, in which the elements of feldspar predominate. The latter, when struck with a hard body, rings like a piece of baked earthenware. The first is often a porphyry.

The rock which is known as petrosilex is a reddish compact feldspar, spotted with crystals of white feldspar. Trachyte being composed of hornblende and glassy feldspar, belongs to this group. Diallage rock might be placed in this connection, as it is composed of diallage and feldspar; but geologically, it is associated with serpentine, and seems in this respect to be separated from the true greenstones.

The dolerites are regarded by some geologists as combinations of labradorite and augite. They may be placed therefore with the pyroxenic compositions, and also as associates of the

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feldspathic rocks. Graystone contains seventy-five per cent of feldspar—the rest is pyroxene. Euphotide is composed of labradorite and sausurite, according to Rose.

The feldspathic group of rocks is quite extensive, including sienite, greenstone, basalt, porphyry, trap, diallage rock, dolerite, graystone, sausurite in euphotide.

Mica, although associated with feldspar in granite, can not be regarded as one of its constant companions: it rarely accompanies it except in the granites of the older periods. The following analyses express the compositions of two kinds of mica:

	Mica.	Lepidolite.
Silex,	46·36	49·86
Alumina,	36·80	33·61
Lithia,		3·60
Potash,	9·22	4·18
Fluoric acid and water,	1·81	3·45
Oxide of manganese,		1·45
do. iron,	4·53	4·18

The composition of mica is very variable; the iron amounts to fourteen per cent. The presence of mica in a rock promotes its disintegration mechanically. Its structure favors the entrance of water into the mass of which it is a constituent part. But this is not all; it contains potash, and hence, like feldspar, it is subject to decomposition. Granites, therefore, composed of large folia of mica, and large crystals of feldspar, are less stable and more subject to crumble than rocks composed of carbonate of lime, or which consist of a simple mineral as hornblende; or if the granite is composed of fine particles, it is more permanent than the coarser varieties. The Quincy and Maine granites are of this description.

Mica is very rarely a constituent of the pyroplastic rocks. The oldest lavas of Etna contain it, and a mass of metamorphic magnesian limestone of the Onondaga salt group occurs near Syracuse, and is associated with serpentine, another product of metamorphic action.

Feldspar seems to be associated with certain vitreous mine-

rals, as pitchstone, obsidian, &c.; or they may be regarded as fused feldspars and augite, in which the former may occur in obscure crystals. Their composition may be stated as below:

	Obsidian.	Pitchstone.
Silex,	72 00	73·00
Alumina,	12·50	14·56
Potash and soda,	10·00	
Oxide of iron and manganese,	2·00	1·10
Lime,		1·00
Water,	0·09	8·50

Pearlstone and pumice are products of volcanic action quite similar to the foregoing. They are composed of

	Pearlstone.	Pumice.
Silex,	75·25	72·52
Alumina,	12·00	17·50
Potash and soda,	4·50	3·00
Oxides of iron and manganese,	1·60	1·75
Lime,	0·50	
Water,	4·50	

There are other products of igneous action, among which siliceous minerals are the common companions, and might be regarded as real geological groups. Thus most of the greenstones, toadstones, and traps furnish varieties of uncleavable quartz, as chalcedony, cacholon, cornelian, jasper, siliceous sinter, &c. All these varieties are nearly pure silica. Their origin is due to the agency of heated water holding silica in solution. They are of course of posterior origin to the greenstones and traps containing them. If we extend this kind of grouping a little further, we shall find associated with the foregoing a family of minerals which were formerly called zeolites, consisting of analcime, laumonite, chabasie, stilbite, heulandite, thompsonite, mesotype, phrenite, &c.; calcspar is frequently associated with them. They are not confined to the greenstones and traps, as talcose and mica slate rarely furnish them. But the pyroplastic rocks are the true repositories of the zeolites, or according to systematic mineralogy, *kouphone*

spars. The following tables exhibit the composition of the most important:

	Analcime.	Laumonite.
Silex,	58·00	48·30
Alumina,	18·00	22·70
Soda,	10·00	
Lime,	2·00	12·10
Water,	8·50	16·00

Laumonite is remarkable for its instability, which is due to loss of its water, when it becomes a white powder. It effloresces in the dry atmosphere.

	Stilbite.	Heulandite.
Silex,	58·08	59·00
Alumina,	16·10	7·19
Lime,	9·20	16·87
Water,	16·40	13·45
Oxide of iron,		10·00

The foregoing family of minerals seem to be due to the solvent action of water. The elements existing in the parent rock are dissolved out under favorable circumstances. The igneous rocks are more or less porous, and hence admit of its transfusion through the mass. If a cavity be opened in a rock, however deep its situation, it is almost impossible to exclude the entrance of water into it, provided the rock is not absolutely anhydrous. At the surface the pressure by which water would be forced into a cavity (which may be regarded as a vacuum) equals fifteen pounds to the square inch: under water the pressure would be greatly increased. The solvent power of water is aided by pressure; hence the transfusion of water into cavities may be accounted for, and indeed provided for, and in its progress through the rock must necessarily dissolve and carry forward the soluble matter with which it meets.

The idea of the transfusion of water into cavities and pores in rocks beneath the sea, is illustrated by Dr. Scoreby's account of a boat pulled down to a considerable depth by a whale, after which the wood became too heavy to float, the air being forced out and replaced by water. So also the filling of empty bot-

tles at great depths in the sea. But the water when forced through the pores of a rock into cavities, becomes a powerful solvent of the earthy salts, which suffer also a transference of matter, which, on crystallizing, constitutes the regular crystals of geodes, cavities, or fissures.

The result of the action of water proves to us that the alkalies and alkaline earths are present in the rock, and that water is competent to dissolve silica. The following exhibits the composition of

	Mesotype.	Leucite.
Silex,	54·46	53·75
Alumina,	19·70	24·62
Lime,	1·61	
Soda,	15·09	
Potash,		21·35
Water,	9·83	

It is proper to remark that the foregoing minerals belong to the submarine division of the pyroplastic rocks. The condition of the submerged rocks is favorable to the development and formation of this natural family of minerals, while the subaerial divisions rarely contain minerals in their cavities, not indeed until they have been placed in favorable conditions for their production. In some instances the foregoing minerals appear to have been formed directly by heat. Those instances may be cited where a rock, as clay slate, has been altered by contact with a trap dyke. Both analcime and garnet have been formed in the slate by the heat of the trap. It is not however clear but that water in this, and most other cases of the kind, has been instrumental in the formation of the minerals under consideration.

§ 43. *Quartz and its group of associates.* Quartz, when interlaminated with mica, forms mica slate, and when associated in the same way with talc, forms the common talcose slates. These mixtures are variable. Sometimes one and sometimes the other predominates. But quartz, although it occurs in the relations I have stated, still it does not seem to hold that relation to talc or mica that feldspar holds to augite

or hornblende. The proportion of quartz is very great at some localities in Maryland and North Carolina, and so large that the mass is regarded as a sandstone. Quartz, however, has its associates among the metals and oxides and sulphurets of the metals. The auriferous formations are so constantly associated with quartz, that it is scarcely ever absent. Even the fine talcose slates, which appear at first much like talc alone, when examined with a glass are found to be made up mostly of fine grains of quartz.

The oxides of iron, when in mass or in veins, are usually accompanied with quartz. Carbonate of lime, which is so common, and as the veinstone of Galena, is rarely, if ever, the veinstone of the oxides of iron. The sulphurets of iron and copper are usually accompanied with quartz, especially if auriferous. It is not well determined how the fissures now occupied with quartz have been filled. Some seem to be disposed to regard them as products of fusion. Black tourmalin is common in quartz, penetrating it in a very remarkable manner.

The talco-micaceous slates furnish the staurotides, garnet, and kyanite. The two former are frequently so abundant that they protect the rock from weathering in consequence of their hardness. Garnet and staurotide are composed of

	Garnet.	Staurotide.
Silex,	43·00	33·00
Alumina,	16·00	44·00
Lime,	20·00	3·84
Oxide of iron,	16·00	13·00
Manganese,	0·25	1·00

Garnet gives different results by analysis; in some the lime is wanting, and in others the iron is increased sufficiently to warrant its use as an iron ore. The manganese too is variable in quantity, and in consequence of the difference of composition it furnishes several varieties, as the precious garnet, the melanite, colophonite, manganesian garnet, &c.

§ 44. *Serpentine group.* Serpentine must be regarded as an igneous product, and like other rocks of this class, it has been

formed at different periods. It is associated with bronzite, diallage, talc, rensselaerite, schillerspar, steatite, chromite of iron, chalcedony, and calcspar. It will be perceived that the grouping of serpentine differs from other pyrocrystalline or pyroplastic rocks. Serpentine itself is composed of

	Serpentine.
Silex,	42·50
Magnesia,	38 63
Alumina,	1·00
Oxide of iron,	1·50
do. chrome,	0·54
Lime,	0·25
Water,	15·00

The associates of serpentine contain magnesia in different proportions; thus bronzite and diallage:

	Bronzite.	Diallage.
Silex,	60·00	52·00
Magnesia,	27·50	15·91
Alumina,		3·18
Oxide of iron,	10·50	7·47
Lime,		19·59

Diallage is also associated with feldspar, and forms with it diallage rock. In this country, however, it is a rare rock. Steatite and talc contain magnesia, but less iron than the foregoing. They are found to be composed of

	Talc.	Steatite.
Silex,	62·00	48·3
Magnesia,	27·00	26·65
Oxide of iron,	3·50	2·00
Alumina,	1·50	6·18
Water,	6·00	9·05

The soapy bed of talc and steatite is characteristic of these minerals. They scarcely differ, as will be seen by the foregoing. Chlorite, a deep green mineral, which often looks and feels like a green talc, differs however in composition. Chlorite is somewhat important as a mineral species; it is usually associated or grouped with quartz, particularly with milky quartz, as in a part of the Taconic range of mountains in Berkshire, Mass. A

supposed chloritic compound forms chloritic slate in combination with quartz, in which respect it is analogous to talcose slate. Its composition is as follows:

	Chlorite.
Silex,	26·0
Alumina,	18·5
Magnesia,	8·0
Soda,	2·0
Oxide of iron,	43·0

Chromate or chromite of iron occurs in serpentine, but where calcspar or carbonate of lime is associated with serpentine, it is often absent, as in northern New York and New Jersey. Octahedral iron, as well as the specular iron, is often associated with serpentine.

§ 45. *Hornblende group.* The associates of hornblende are feldspar, pyroxene, and quartz. It sometimes stands by itself, or has no intermixture of feldspar or quartz. But generally feldspar is present, and the two minerals are arranged in parallel stripes, appearing like a stratified rock. Quartz is never abundant in this compound.

Hornblende is associated with feldspar in another class of rocks—the pyroplastic, the greenstones, or as they are sometimes called, dolerites and diorites. Their structure is more or less granular, and the feldspar may be seen in white crystalline grains, sometimes by the naked eye, but in many instances the eye requires the aid of a magnifying glass. It appears that the hornblende in these compounds is greater than that of feldspar. Sometimes again the feldspar is in quite large crystals, giving the rock a spotted appearance. It has become a greenstone porphyry. This is the case in many places situated in the outburst of greenstone along the Hudson and Connecticut rivers.

Chemists have paid but little attention to the composition of rocks, and hence it is impossible to group them as perfectly as it is wished. Our trap dykes, which are usually so homogeneous and compact, afford no external clue to their composition. They may be hornblendic, or they may be pyroxenic. The

absence of magnesia would lead us to place them in this group. Epidote and titanium are common associates of hornblende, especially the rutile and silico-calcareous oxide of titanium. Hypersthene is often associated with it, but commonly with labradorite. It is composed of

	Hypersthene.
Silex,	54·25
Alumina,	2·25
Magnesia,	14·50
Lime,	1·00
Oxide of iron,	24·50
Water,	1·00

§ 46. *Pyroxenic group.* In combination with feldspar, pyroxene forms basalt. This rock is black and perfectly compact, or formed of particles which are indistinguishable by the naked eye. It is the most important of the group. The melapyres are also combinations of these minerals, to which may be added obsidian, pitchstone, and peperino. These volcanic products have but little interest in the eyes of an American geologist. As a mineral, pyroxene is associated with, and hence might be grouped with, our pyrocrystalline limestone and serpentine. It is not common to those serpentines which are not associated with lime. But neither hornblende nor pyroxene enter into combination with limestone as a rock.

§ 47. *Limestone group.* The class of limestones under consideration, though they contain many minerals, yet as a rock, it is not associated with any important ones, except serpentine and its congener rensselaerite. Serpentine in this grouping is subordinate to the limestone. Specular oxide of iron occurs in beds in this rock in northern New York.

The circumstances under which this rock occurs in this country warrants its recognition as a rock quite as distinct from all others as granite. It is by no means a metamorphic mass. When this rock occurs among granites, it is massive and unlaminated; when it occurs among gneiss, mica slate, and hornblende rocks, it is laminated. It might perhaps be grouped

with all these rocks, as in New York, Massachusetts, and New Jersey, where it frequently accompanies them.

The pyrocrystalline limestones abound in pyroxene, hornblende, chondrodite, brown tourmalin, spinelle, sulphurets of iron and copper, and phosphate of lime. In veins of Galena calcspar is often the gangue. The foregoing minerals never form rocks in combination with limestone, excepting serpentine. The minerals imbedded in limestone have a peculiar composition, though it may not be due to the rock in which they occur. Thus chondrodite and spinelle are composed of

	Chondrodite.	Spinelle.
Silex,	32·66	2·00
Magnesia,	51·00	12·00
Peroxide of iron,	2·33	16·00
Fluoric acid,	4 08	
Potash,	2·10	
Water,	1·00	
Alumina,		68.00

In the compositions of tourmalins boracic acid is found. It is a rare substance. It is volatile at a high temperature, but possesses active solvent powers. The dissolved matters crystallize from its solutions. Black tourmalin is composed of

	Black Tourmalin.
Silex,	36·03
Alumina,	35·82
Magnesia,	4·44
Lime,	0·28
Potash,	0·73
Soda,	1·56
Oxide of iron,	12·71
Manganese,	0·75
Boracic acid,	4·02

Tourmalins accompany the coarse granites. They are quite rare in the greenstones. A vein of green, red, and blue tourmalin occurs in the coarse granite at Chesterfield. They are more commonly disseminated in the rock, especially the indicolite, and sometimes so abundantly as to have given its name (schorl rock) to the compound. Graphite in tables, and

sometimes in regular hexahedral tables, is one of the most common minerals of pyrocrystalline limestone. When it is considered that graphite is a furnace product, we can scarcely entertain a doubt respecting the agent which was instrumental in its origin. This mineral, however, is absent in those rocks which are usually regarded as the metamorphic limestones, as the marbles of Berkshire, Mass., and which are prolonged to Canada on the north, and to Georgia on the south. The green crystallized mica, the brown zircons, sphene, corundum, sulphuret of iron in fine crystals, prismatic feldspar, crystals of quartz in dodecahedrons, carbonate of iron, yellow and brown tourmalins, are among the simple minerals of this rock.

The simple minerals which we find commonly associated with certain rocks may be regarded as having originated under three conditions: the first, those which belong to the granites and pyrocrystalline limestone; these have been developed through the agency of high temperature. The second, those which belong to the mica and talcose slates; these have required for their production only a moderate amount of heat. The kyanites, garnet, staurotide, andalusite, belong to this series. Third, those which are developed in thin seams (not veins) and cavities of rocks, mainly through the instrumentality of water. As examples, stilbite, heulandite, thompsonite, chabasic, &c., may be cited.

The rocks admit of grouping to a certain extent according to the period during which they were formed, or according to the minerals which enter into their composition. The feldspathic rocks belong to different periods—the most crystalline to the earliest, the amorphous and subcrystalline to later periods. To the former belong the granites, and to the latter the greenstones. The schistose rocks, gneiss, mica and talcose slates, together with hornblende, are closely related, and were evidently formed under a diminished temperature. It was temperature, and not water, which arranged their laminæ into parallel layers, a result which is sometimes imitated in furnace operations. We find no sediments beneath, or intercalated between them.

PYROGENIC OR ERUPTIVE ROCKS.

§ 48. *General considerations respecting pyrogenic or eruptive rocks.* Pyrogenic or eruptive rocks have five phases, each of which should be described. The five phases are recognized by the structure of their masses. The first have a symmetrical arrangement of their component parts in consequence of their crystallization. Thus the feldspar of granite is crystallized; and however small its particles, it is perfectly separated from the other minerals of the mass, whatever they may be. The mica also is crystallized, and the quartz, though massive, is equally distinct. Each mineral composing the rock is clearly defined in its boundaries, and is a fact attested by the eye. This structure, which belongs to the mass and each mineral composing the mass, is the first phase among the pyrogenic rocks. The second phase preserves the isolation of particles, whose crystallization took place at the time when, and at the place where, they now remain; but the particles of minerals of the same in kind are arranged in parallel stripes or layers. The feldspar is arranged in its stripes or bands, the mica or hornblende in their bands respectively, and they may alternate with each other. The rock presents a striped aspect. Such an arrangement of parts is properly called lamination. Gneiss, mica and talcose slates, and hornblende are examples of this kind of structure. The third aspect, the separation of particles, is too indistinct to be recognized, or it is far less so than in granite. A single element of the rock may be imperfectly crystallized and isolated, while the particles of the mass remain indistinct, or it may be granular. Greenstones and porphyry are the most distinctive examples; the first is both massive and columnar, and it may be laminated, but the lamination is not distinguished by the arrangement of different minerals in parallel bands or stripes; but the laminæ are all of the same kind of matter while separated from each in thin sheets. This structure is not uncommon. The fourth aspect, the rock is vesicular. In fusion the mass became pasty, and the confine-

ment of the air, which is expanded by heat, forms the vesicles, the sides or walls of which are stiffened before the heated air escapes. The vesicles are large and small, and these may be arranged in stripes. Sometimes the vesiculation expands the mass sufficiently to render it buoyant on water as in pumice. Crystalline structure is wanting in the vesicular rocks. The fifth aspect which rocks of igneous origin present, is that of a glass; it is a vitrification of the rock; it is sometimes homogeneous or striped. To the eye it appears like a furnace production. Under certain circumstances the vitreous mass may be converted into fine glassy spiculæ. These spiculæ often cluster together, and form a flaxen appearance. The rock glasses contain less alumina than feldspar. Their composition, though variable, may be represented as follows:

	1 Obsidian.	2 Obsidian.
Silex,	60·52	84·00
Alumina,	19·05	4·64
Oxide of iron,	4·22	5·01
do. manganese,	0·33	
Lime,	0·59	2·39
Magnesia,	0·19	
Potash,	10·63	
Soda,	3·50	3·55

The 1st is from Teneriffe, the 2d from Iceland.

The sixth aspect occurs in those rocks where heat and mechanical action is so combined as to reduce the mass to powder. Volcanic ashes are examples of this form. The particles are buoyant in the air, and are carried or transported by winds sometimes for hundreds of miles. The foregoing examples are all distinct in the extremes; indeed, except in a few cases, they may be recognized by the student without difficulty. They may, it is true, graduate into each other. It is sufficiently plain, however, that fire, acting with different degrees of intensity under different circumstances, and acting too on compounds variable in fusibility, must furnish a variety of results which are not perfectly classifiable. There will necessarily occur some intermediate results, belonging in

part to one kind of structure, and in part to another; still the examples described in the foregoing paragraphs, constitute the distinctive kinds of structural arrangement, which result from the common action of heat upon rocks, and the structure which results from the different degrees of it, furnish the grounds upon which they may be separated into classes or groups.

We have already taken occasion to speak of structures, as affording indications of the age of the pyrogenic rocks, and it appears that at one extreme of time the rocks formed were all crystallized, while at the other extreme they all want it. The first belongs to the most remote period which any of the geological phenomena recorded in earth's history, have furnished; the last belongs to the present, or to the action of the present periods, and form only lavas, slags, sands, and porous products, but no granites. The pyrocrystalline, therefore, differ from other rocks of the pyrogenic kind, in structure and age, though they are not confined to one age or period. By the modification of structural arrangements under the influence of heat, varying in intensity, we may separate the pyrocrystalline rocks into two groups. In the first the massive structure prevails, in the second the laminated. These distinctions have been already illustrated.

The special characters of each group, together with its members, will be given in the proper place.

CHARACTERISTICS OF THE PYROGENIC OR ERUPTIVE ROCKS.

§ 49. *The massive pyrocrystalline rocks.* The first characteristic possessed by this class of rocks is, the perfect separation of each individual of the mass, by crystallization. The second is the indiscriminate arrangement or mixture of the minerals, without regard to lamina, bands or stripes. They are composed of feldspar, mica, quartz, limestone, hornblende and augite. But a separation of parts of the mass is effected by crystallization, which has affected the rock as a whole. They are represented by those which are referred to under the first phase, § 48.

§ 50. *The laminated pyrocrystalline rocks.* They possess the first characteristic of the preceding class. Their second characteristic consists in the arrangement of the component minerals into parallel bands or stripes. In the third characteristic they agree again with the preceding section. They are referred to under the second phase of the preceding section.

§ 51. *The pyroplastic rocks.* The first characteristic consists in their homogenity, or an approach to it. When compact, they are perfectly homogeneous; when granular, it is sometimes possible to discover the mixed nature of the mass by the occurrence of whitish particles in a granular ground, or the ground or base may furnish individuals distinguishable in size, as the basalts, the greenstones, trap, and porphyry. They belong to rocks indicated under the third phase of the section already referred to. The mass may be laminated, or rather sheeted, columnar or massive, or the mass may be vesicular, but the vesicles are not empty. The circumstances connected with their cooling have modified their structure. A part have cooled beneath water, or the sea, and a part have cooled in the atmosphere, and hence the subdivision of the class into *submarine* and *subærial.* The subærial products are numerous. They may be porous, vesicular, glassy or vitreous and compact; vitreous and fibrous, like hair, or in the condition of an ash. In the vesicular structures, the vesicles are usually empty. They are referred to under the fifth and sixth phase of § 48. They are the modern volcanic products.

OF THE MEMBERS OF THE MASSIVE PYROCRYSTALLINE CLASS.

§ 52. GRANITE. *The primary, hypogene and igneous, of different authors.* It consists of feldspar, quartz and mica, commingled together, forming a mass in which their arrangement has no order which can be discerned. Each mineral may predominate in different localities, though it is rare for the quartz to exist in excess over and above the feldspar and mica. The individual minerals have no allotted size; the mass may consist of small

particles, or they may be very large. Hence, when the particles of composition are regarded, a granite is fine or coarse. Granites differ in color. The fine are gray, usually; the coarse are white, or nearly so. Granites of an intermediate texture may be either gray or flesh color. The fine and very coarse are rarely flesh color. The quartz is sometimes rose red, but usually gray, and never crystallized. The mica in the fine granite, is nearly black. In the coarse, the mica is greenish, and in some cases black or very dark green. Mica is frequently wanting. Sometimes its place is supplied by hornblende. This last commixture of minerals constitutes the sienite of authors, provided the arrangement is granitic; or if the mica is intermixed with hornblende, it is still regarded as a sienite.

The variability of granite is seen in its coarseness or fineness. The extreme of these kinds will be found in the veins, traversing gneiss, or mica slate. The mica and feldspar is in large sheets and blocks; the former occupying, very frequently, the middle of the vein, and standing with its edges to the center. In other varieties where albite is present, this occupies the center, and is arranged in imperfect stellated laminæ, which are usually hemitropic. Such is the case with the veins of coarse granite at Chester and Chesterfield, Mass. These veins are well defined at their borders, and usually contain some variety of tourmalin. It is mostly indicolite at Chester, but at Chesterfield, black, blue, green, and red occur. So at Topsham and Brunswick, Me., the coarse granites resemble those already referred to. Their width varies from one inch to forty or fifty feet. The hills of primary rocks, of which these coarse veins form a characteristic feature, are peculiar to the New England states, extending on the south to the Long Island sound, and to Maine on the north.

The coarse granitic beds occur at numerous places. Chester, Russell, South Hampton lead mine, Granville, northern New York, Pennsylvania, New Hampshire and Maine. The feldspar is white and bluish white, and predominates in the mass, while the mica is poorly represented. Feldspar in moderately large

blocks, of a flesh red, occur at Granville. Another coarse granite is found in Williamsburgh, Mass., in which the mica is plumose. These coarser granites are frequently porphyritic, and the feldspar is the most prominent mineral; but these varieties pass into the finer kinds, and also into gneiss, and might be designated by the descriptive name, granitic gneiss. This variety is well exhibited in the rocks of St. Lawrence county, N. Y., where the granitic rocks are more frequently of a character which places them in intermediate positions. The fine granites of New England, fine in texture, have long been known at Quincy, Chelmsford, Fitchburg, and Sharon. In Maine the granites are both fine in texture and fine in quality. They form the caps of hills, and the mass not being remarkably thick, it has frequently been removed, exposing the gneiss or mica slate upon which it rested, and also bringing to view the dykes through which the molten matter had reached the surface. It is probable that these masses, capping the hills, have been greatly reduced in thickness by denudation. Some of the granites are fine, and have a red color of a uniform tint; others are gray, with a greenish tinge; and others still dark green, from the presence of both mica and hornblende. It is unnecessary, however, to attempt to describe all the varieties of granites of this country. Some of the best, for building stone, belong to the gray fine-grained kinds, which flowed through narrow fissures in mica slate or gneiss, and which appear to have overspread large areas, as those beds in the neighborhood of Augusta and Hallowell, in Maine; while those which are coarse occur in veins in gneiss or mica slate. These usually furnish feldspar in larger blocks, free from iron, and it is often suitable for the manufacture of porcelain. The granites whose mica is in large folia, are unsuitable for building, or works of construction. The granites of the Rocky Mountain range resemble the common gray and flesh colored granites of New England.

§ 53. *Age of granite.* Granite, as it is described in the foregoing paragraphs, may or may not be connected with the oldest masses of the globe. Its age and position is indetermin-

able, in consequence of concealment by the soil, or by the adjacent rocks. Fig. 5 illustrates this position. If a complete section of a hill in which a mass of granite cropped out, it might disclose granites of three periods, a, b, c (Fig. 2, p. 45), but if a portion only of the mass, a, could be seen, and a portion only of b, it would be difficult, if not impossible, to say whether the two masses were of the same age or not. Sir Charles Lyell has demonstrated that the oldest granites usually rest upon the newer, and hence the term *hypogene*, the nether formed rock. The newer rocks may be connected with the surface by dykes or veins, as at a. In this case the masses of the rock with which they are connected, have cooled against the under side of a more ancient mass. Now that it is understood that cracks and fissures are formed in the rocks by cooling, it is no longer difficult to explain how veins of granite, as well as the metalliferous veins, are occasionally found in sedimentary as well as in those of igneous origin. Those rocks which repose upon an igneous mass, are more frequently traversed by veins than others which are superimposed upon them, proving that they are nearer the source whence all the fused materials originate. The age of granite, whether in veins or in dome-shaped masses, can be determined only approximately. If a mass of granite overlies the carboniferous rocks, it is certainly as new as those rocks, but it is possible it may be more recent than the trias, or new red sandstone.

Fig. 3.

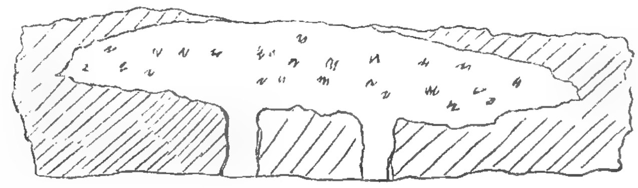

Fig. 3 illustrates a small mass of granite, in Chester, Mass., where the bed is connected with two veins which penetrate through a fine mica slate. The bed itself was formed undoubtedly by an overflow of granite which passed through the vertical veins. This illustrates, on a small scale, the formation of some of the

large beds of granite in Maine, and other parts of the country. We have not as yet discovered granite as new as the cretaceous system in this country, while in the Alps this rock penetrates the chalk formation. It appears, from observation, that many of the most imposing outbursts of granite were accompanied with important changes of level of the earth's surface, and consequently affected more or less animal and vegetable life.

§ 54. *Distribution of granite in the United States.* The granites of this country furnish the usual varieties which have been described by foreign authors. Two of the most common departures from the normal kind is composed of quartz and feldspar, the mica being absent, and that which is composed of quartz, feldspar, and hornblende or pyroxene—the two replacing the mica. Whatever change the rock has undergone, it retains the massive structure of granite. A less common variety receives talc in the place of mica, and is called protogene, and forms that kind which is liable to decomposition, and which furnishes one of the porcelain clays. The soda granite at Gouverneur contains large crystalline masses of albite, though frequently in perfect hemitrope crystals, associated with carbonate of lime.

§ 55. *Granites of northern New York.* In northern New York the granites are exceedingly variable in composition. In this district they become metalliferous, and in this respect differ from those of New England. In Clinton county a flesh-colored granite is traversed by lodes of magnetic iron. The state prison, located in that county, is built upon lodes of this rock. The magnetic iron of Arnold hill, in the same county, is in the same rock. One vein of this hill is a peroxide. The granite of St. Lawrence county is in part similar to the New England granite, particularly that variety which is found at Alexandria bay. It forms the Thousand islands of the St. Lawrence, and contains schorl and imperfect garnets and epidote. The most common kind of this county is associated with limestone. It is underlaid and traversed by seams or veins of coarse crystallized limestone. The rock itself is also coarser

than it usually is. It is also the repository of many minerals. The peroxide of iron, barytes, strontian, carbonate of strontian, albite, pyroxene, hornblende, fluorspar, and sulphurets of iron and copper belong to this rock. It should be stated that the rock decomposes readily, and where exposed upon the lake or river shore, becomes cavernous. The ores and minerals occur in nests and strings, which run out, and hence has ever proved an unsafe rock in mining. The most common variety of granite occurring in the low ranges of the Blue ridge is composed of feldspar and quartz. It is always in irregular veins, and is sometimes auriferous. In other respects it is barren of minerals, and in decomposition forms a porcelain clay. It is common in Guilford, Davidson, Cabarros, Mecklenburg, and Rowan counties, in North Carolina, and is associated with greenstone in dykes. A similar granite occurs in Macon and Cherokee counties. It is not uncommon in the Nantahala range, a spur of the Blue ridge.

§ 56. *Granites of the New England states.* In Vermont, granite occupies a portion of the eastern slope of the Hoosick Mountain range. It does not appear in the western part of the range, but comes in east of Montpelier.

Maine furnishes, however, some of the finest fields of architectural granite.* It is light gray, of fine texture, and works easily. Columns from thirty to fifty feet in length may sometimes be split out from the quarry. The granite of Hallowell lies in sheets or thick laminæ, which may be reduced to columns by splitting in lines parallel with the grain of the rock. These granitic beds may be said to be sheeted, in consequence of the easy and ready cleavage of the mass on a large scale. Indeed, it is a spontaneous separation into laminæ, varying in thickness from one to three feet. It is not well determined how the granite received this peculiar structure. It is probable, however, that it owes its sheeted structure to its flow at the time of its eruption, and the consequent cooling

* Jackson's Maine Reports.

of the mass. It approaches gneiss in its structure, but differs from it in wanting the arrangement of the mica planes. This example, however, proves that a sheeted structure is not due to the action of water, and was never arranged into beds like the sedimentary rocks.

The granites of the New England states lie in ranges, inclined upon the eastern slope of the Hoosick Mountain range. At the south-western corner of Vermont a field of granite forms a portion of the western side of the Hoosick mountain, upon which repose the lower members of the Taconic system. But most of the New England granite lies adjacent to the Atlantic coast. It is divisible into those granites which have been erupted from comparatively narrow fissures in gneiss, mica slate, and an older granite, or those granites which have erupted from fissures, but which seem to have overflowed wider areas, and whose structure is more or less sheeted, like the granite of Hallowell in Maine; and lastly, those granites which are still more widely spread, and more ancient than the preceding. It is impossible, however, to draw lines of distinction between the last two kinds of granite, except when the last is traversed by the preceding granites in veins.

§ 57. *Granites of the Appalachians.* The granites and sienites of the southern Highlands upon the Hudson river resemble those of New England. They pass southerly into Pennsylvania, some of which contain zircons and octahedral iron. In the county of Philadelphia the gneiss and mica slate is traversed by coarse veins of granite, the feldspar of which decomposes into kaolin. So near Manayunk, the mica slate which abounds in garnets is intersected by numerous veins of granite, in which feldspar predominates. Chester and Lancaster counties furnish numerous localities of granite.

In Virginia, granite and sienite are not common rocks Those which occur form a part of the Blue ridge. Both occur in Halifax and Campbell counties on Staunton river and Whipping creek; also on James river four miles above Greenway. This is a formation of sienite, and is well adapted for works

of construction, dams, culverts, viaducts, &c. It extends many miles in length. Granites only slightly elevated above the general level of the country form a low and rather continuous ridge, extending through Virginia, North and South Carolina. This ridge forms the first waterfall of the Rappahannock, James, Roanoke, Tau, Neuse, and Cape Fear rivers. It is often a variety which may be called a gneiseoid granite.

Granite underlies in part the counties of Guilford, Davidson, Rowan, Mecklenburg, and Lincoln. The belt extends south into South Carolina. But a compound of feldspar and quartz is one of the most common rocks at the base of the Blue ridge. Granite is by no means a common rock in the higher parts of the Hoosick mountain and the Blue ridge. The most common rocks of these high ranges are mica and talcose slates, hornblende and gneiss.

On the west side of the Blue ridge granite is equally scarce, and when it occurs it is mostly in veins, and consists of quartz and feldspar, a rock which is sometimes extensive. It decomposes, and forms a great abundance of white clay. About four miles west of Ashville, Buncombe county, a handsome granite suitable for architecture crops out and crosses the road; but most of the rocks skirting the French Broad river are gneiss and mica slate. Granite occurs four miles east of the Warm springs: it rises in a dome-shaped mass, and supports quartz and slate rocks, the lower members of the Taconic system. South-westward and westward from the Warm springs all the rocks to the Mississippi river belong to the sedimentary class. Granites of the same kind and character appear in Macon and Cherokee counties, and from thence they extend into Georgia. They never form large and important masses among the rocks. To the south-west and west of the Mississippi granite occurs, and forms in part a low range of mountains, which have been called the Ozark mountains. Their tops rise like islands in the midst of cretaceous seas. In the Thousand isles of the St. Lawrence, and so onward to the west in the Lawrentine chain, granites and sienites are far more common than in the Appa-

lachian range. This range is flanked on all sides with the oldest sedimentary rocks. In the British provinces, Nova Scotia and New Brunswick, granites resembling those of Maine are well known. They range, with some intermission, from Canso to Halifax, bordering a low rocky coast.

§ 58. *Granites of Oregon and California.* Granite of several kinds is a constituent part of the great mountain ranges of Oregon and California. It is associated with traps, basalts, sienites, and mica and talcose slates.* According to Dr. Pickering, granite forms a part of the Cascade mountains, having met with it about twenty miles north of mount Rainier. The summit of the pass of this range is however trachyte. North of Okanagan, and east of fort Colville, granite is the prevailing rock. But it occupies, according to Dr. P., an anomalous position, the summit of the range being formed of basalt or trap, while the sides only are granitic. Farther south, according to Professor Dana, or between Oregon and San Francisco, albitic granite is a common rock of the principal ranges, especially of the Shasty mountains. This is sometimes porphyritic. The color of the granite is usually light, and fine grained, constituting a firm mass, and little subject to decomposition; though when changed it is as white as chalk. Sometimes the albite is red. The rock is barren of minerals. The Rocky Mountain range has its share of granite in its composition, though sedimentary rocks reach the principal passes of the chain on the eastern slope.

§ 59. *Granites of lake Superior.* The northern side of lakes Superior and Huron, together with the highlands of Wisconsin and Michigan, and between the Upper Mississippi and Michigan and Superior, is another extensive field of eruptive rocks, among which granitic and sienitic protrusions are very numerous. It is a region covered with drift, and hence no small parts of the rocks are hidden from view.

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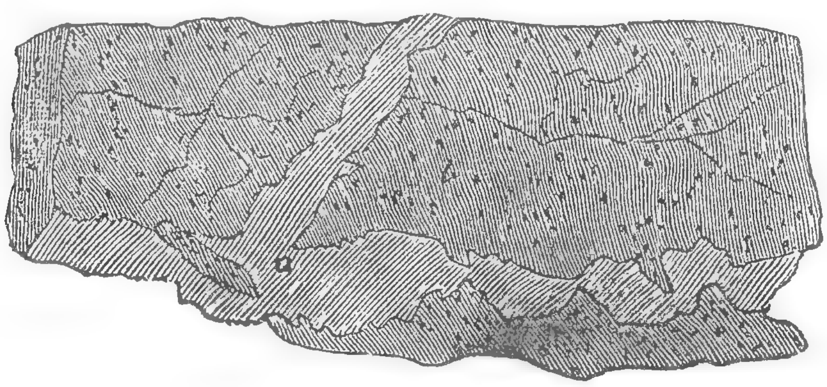
* Dana's Report U. S. Exploring Expedition.

SIENITE.

§ 60. Sienite is a granite in which hornblende takes the place of mica. This is more abundant than mica. The latter may be present in small quantities, and it may be absent. This rock is to be distinguished from hornblende rock, however, by the absence of lamination. Its structure is granitic in the true sense of the word. Taking granite as the type of sienite, it may, like the former, be divided into varieties, either by the absence of one of its elements, or by the form or shape which one of its elements has assumed.

§ 61. *Feldspar and hornblende.* By reference to the composition of greenstone, it will be seen that this is also composed of the same substances, but the particles in greenstone are minute, and unless it is porphyritic, it appears homogeneous. But this variety is made up of distinct particles of hornblende and feldspar. There is, however, a gradation of this variety into greenstone, or an approach to greenstone. This fact may be observed at Nahant in Massachusetts.

Fig. 4.



a Limestone, *b* Granite.

Sienite and granite are often associated with limestone. Orange and St. Lawrence counties furnish many instances: fig. 4 is an example of the relation of the two rocks at Fowler, St. Lawrence county. The figure shows the structure of granite.

That limestone is strictly a pyrocrystalline or eruptive rock at all the localities which I have cited, appears from the fact that where it is in contact with the Potsdam sandstone the latter rock is vitrified. It has lost its granular structure, and

near its junction with limestone it has become porous, preserving at the same time its vitrified character, and its disposition to break with a conchoidal fracture. Its luster is resinous rather than vitreous. One of the most interesting localities is at Theresa on Indian river. The junction of these rocks may be observed in a gorge below the falls of the river. Many interesting points are exposed in the vicinity of this place, either in the iron mines or the various ravines connected with the creeks in the vicinity.

Fig. 5.

1 1 Gneiss, 2 2 Primary Limestone, 3 3 Potsdam Sandstone, changed at its junction with the limestone into vitrified quartz.

The common kind of sienite is composed of feldspar, quartz, and hornblende, arranged as the minerals are in a true granite. The quartz is usually a light smoke gray, the feldspar is also usually gray; but in some cases the latter is red. These minerals are mixed uniformly together, and the individuals are small. If mica is present, it does not materially alter the appearance or character of the rock: ususally both are black and in small particles. The whole compound will be fine-grained, and in this condition constitutes a good building stone.

§ 62. *Porphyritic sienite.* The feldspar in this variety appears in large individuals, imbedded in a finer ground. Either of the preceding varieties may pass into this by a change in the size of the particles of feldspar.

Sienite occurs in Orange, Essex, and Clinton counties in New York, and in several counties in the eastern part of Massachusetts, particularly in the vicinity of Boston. So also sienite is a common rock in Pennsylvania, Virginia, and North and South Carolinas. In Virginia it occurs in Nelson and

Augusta counties, forming one of the rocks of the Blue ridge, where it is associated with gneiss and granite. At this place it is a dark gray porphyritic rock, and contains epidote. In North Carolina it forms a wide belt, running northeast and southwest in Randolph county, and on towards the narrows of the Yadkin. It is a black tough rock, in which hornblende predominates, and in which quartz is only sparsely scattered through it.

The rock quarried at Quincy, Cape Ann, and at other places in the eastern part of Massachusetts, and which is so well adapted for columns and the walls of buildings, is more closely allied to the true granites. These are not tough and difficult to be quarried, because the hornblende is never in excess.

To the foregoing varieties there might be added a pyroxenic sienite—a kind in which pyroxene forms a perceptible part of the rock. Sienite is more closely related to greenstone than to the ordinary granites, and it often passes into the former rock.

HYPERSTHENE ROCK.

§ 63. This rock is regarded as a granite. In constitution it differs from the common granites in being composed of labradorite, feldspar, and hypersthene, the last of which is allied to hornblende. The feldspar contains lime and soda. Its composition has already been given. The color of this rock is usually a smoke gray. The color of the labradorite, however, determines the color of the rock. It has the usual granitoidal structure. This results from the crystallization of the feldspar, a portion of which is fine, and represents the base, in which there is imbedded individuals of a large cleavable size. These cleavable individuals present very frequently a beautiful opalescence of bronze, yellow, blue, and green colors. In the mechanical arrangement of its particles of composition it resembles a porphyry; but the rock chemically considered consists mostly of labradorite, the hypersthene being extremely rare in it. The rock is destitute of mica, and almost of quartz; and if quartz and common feldspar occur, they are subordinate

to it. The characteristics of the rock are derived from the labradorite. Hornblende and pyroxene both replace the hypersthene at certain localities. This rock, when changed by the action of the weather, becomes light colored, and resembles the gray granites. The atmosphere acts upon the rock in stripes or bands, which run in the direction of the natural joints. The action of the atmosphere, rains, and frosts is as great as upon any of the known granites. Upon the tops of the Adirondacks large masses are strewed over the surface like huge boulders, but still in situ having been quarried out by atmospheric agencies alone.

There are but few varieties of hypersthene rock which are worthy of special notice, of which the following are the most important:

1. The first is composed wholly of labradorite, though to the eye it has the aspect of being made up of two distinct minerals.

2. Labradorite and hornblende. The hornblende takes the place of hypersthene, though sometimes the latter is still present.

3. Labradorite, hornblende, and epidote. The latter, however, never occurs in sufficient quantity to change the character of the rock.

4. Granular labradorite and mica. This variety is quite dark, and resembles a trap. The mica is in tufted, radiated masses, and almost black. It occurs usually at the junction of the rock with gneiss.

Magnetic iron in grains is diffused or disseminated through the rock. It is black, with a resinous luster. Its obedience to the magnet serves to distinguish it from other dark-colored minerals.

Hypersthene rock is traversed by a double system of joints, in consequence of which it often appears in the process of separating into large tabular masses. One set of joints run S. 5° W. The separation of tabular masses is frequently in the direction of the slope or side of the mountain where the rock occurs. A separation of the masses also often takes place in

the veins of segregation, and the rock also cracks into wedge-form masses.

Like other granites, this rock decomposes, and forms a clay, which is quite refractory in the fire; but it is never so white as the purest porcelain clays. In this natural or spontaneous analysis, most if not all of the granites furnish, in connection with the pure alumina, oxide of iron, peroxide of manganese, and crystallized silica.

The hypersthene rock is confined mostly to northern New York. The western part of Essex county is made up entirely of this rock. It forms all of that group of mountains in this part of the state which are known as the Adirondacks. A train of bowlders, derived from this cluster of mountains, passes through Amsterdam, thirty miles west of Albany. It extends to Orange county. Another train of bowlders range along the St. Lawrence in St. Lawrence county, New York. This train came from another group of mountains far to the north or northeast, probably Labrador. It has no connection with the Adirondacks.

This rock receives a fine polish, and would form beautiful tables and other ornamental articles of furniture. The most important mineral associated with this rock is the magnetic iron ore. Prehnite, chalcedony, and albite are found in this rock, though by no means abundantly. It is poor in minerals. It contains subordinate beds of pyrocrystalline limestone, which are rich in minerals: those, for example, which are common to it when it is associated with other rocks.

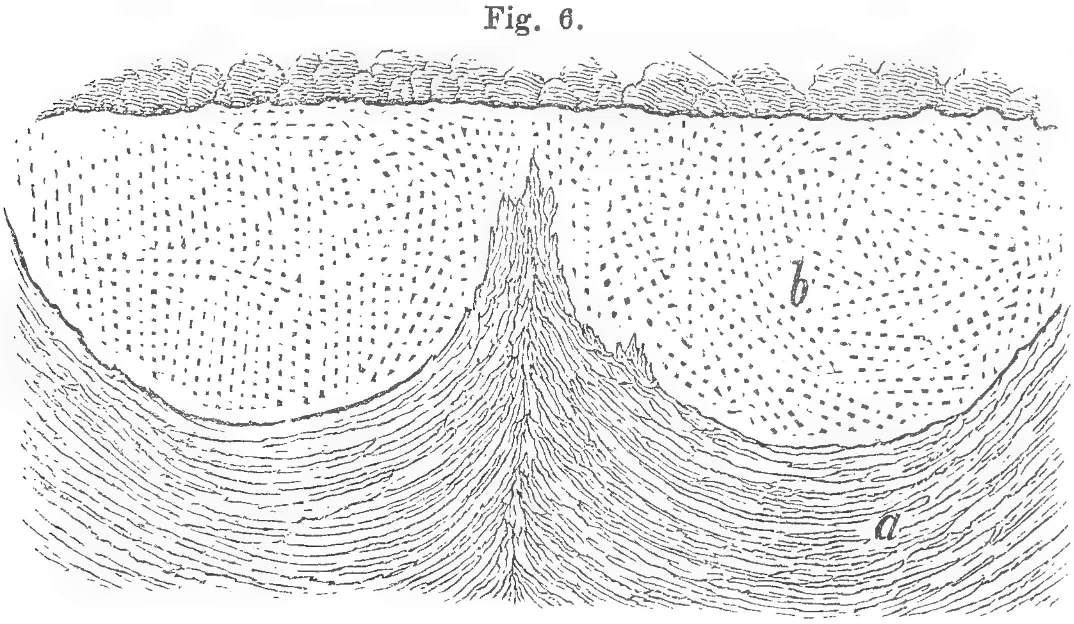
The area which this rock covers is small when compared with the common varieties of granite. In the United States it is mostly confined to the region occupied by the Adirondacks: though I have observed a few small patches in other parts of New York, they are too inconsiderable to require a notice in this place. It is impossible to determine even approximately the age of this rock. It is isolated and disconnected with fossiliferous rocks. The elevation of the Adirondacks, however, was probably subsequent to the consolidation of all the

lower Silurian rocks. Upon lake Champlain the evidence of movements of a much later date are fully established. The fact that these movements have taken place since the drift, was made known long ago in the reports of the New York survey. It can not be determined whether they extended to the central mass of mountains, situated between lake Champlain and the St. Lawrence. All that portion however of the hypersthene rock which extends to the lake has been raised about five hundred feet since the drift period.

PYROCRYSTALLINE LIMESTONE.

§ 64. *Primary limestone—metamorphic limestone in part.* There can be no doubt that limestone occurs among the most ancient consolidated rocks of the globe. The investigations which I made sixteen years ago satisfied me on this point. At that time no one had entertained this view in this country.* The rock is coarsely crystalline, usually white, or gray, or greenish, rarely blue. It occurs in beds beneath granite, and

Fig. 6.



a Limestone, *b* Granite.

frequently underlies and penetrates it as in fig. 6: *a* limestone, *b* granite. The locality where it may be observed beneath granite is one and a half or two miles south of Clintonville,

* New York Geological Report for 1838, for the northern district.

New York. The line of demarkation between the two rocks is perfectly distinct. Its occurrence in veins in granite (figs. 7 and 8) is conclusive of its igneous origin; it proves that like granite it has undergone fusion, and has been injected into cracks and fissures of the superincumbent rock.

Fig. 7.

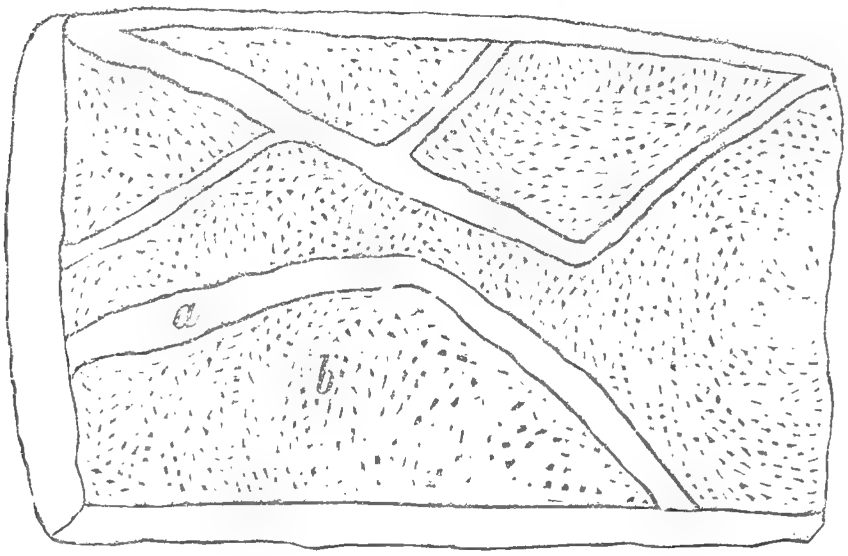


Fig. 7.—Ground plan of a system of veins in granite, as they occur at Gouverneur, St. Lawrence county, New York. These veins extend for many rods in length, and ramify in manner similar to granitic veins. Many localities occur in St. Lawrence, Jefferson, and Essex counties. They furnish an arrangement different from the foregoing, but in keeping with it.

Fig. 8.

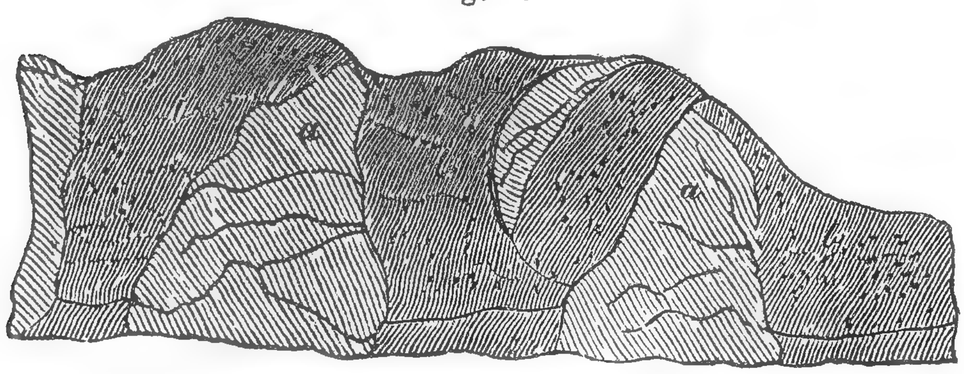
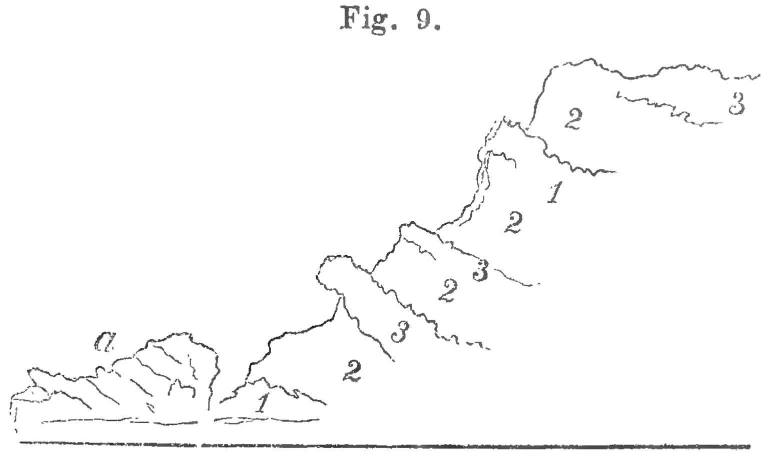


Fig. 8 shows a vertical section of portions of the same vein, where they terminate laterally in a broken ledge of granite, showing that they descend into the mass of granite, or in other

words, the mass was erupted through cracks or fissures in the rock.

It contains scapolite, hornblende and pyroxene, spinelle, octahedral iron, fer-olgiste, graphite, mica, talc, phosphate of lime, brown tourmalin, serpentine, &c. The districts of this variety of limestone are limited. In St. Lawrence and Jefferson counties it occurs just within the band of the lower Silurian rocks; in Essex and Clinton counties, at Moriah and near Clintonville; also in the western parts of Essex and eastern part of Hamilton counties, in the vicinity of the Adirondack iron works; in Canada West, also, twenty miles west of Ogdensburg. This district is identical with that of St. Lawrence and Jefferson counties. The granite of the Thousand islands lies between the two districts, and is entirely destitute of limestone of this kind and the minerals it contains. In Orange county, New York, and the adjacent part of New Jersey, Sussex county, primary limestone, containing spinelles and most of those minerals already noticed, forms a band of considerable extent. The red oxide of zinc, sapphire, and chondrodite are minerals which have not as yet occurred elsewhere, excepting the latter, which is found in small quantities only in northern New York.

Fig. 9.

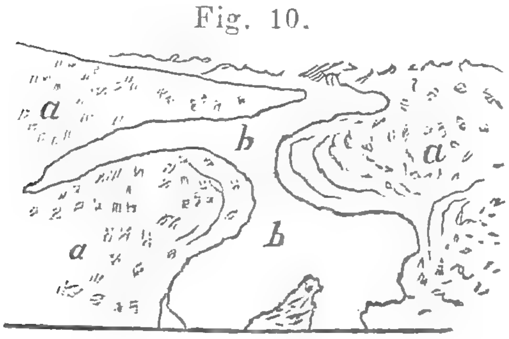


a Potsdam and Calciferous Sandrock, 1 1 Hornblende, 2 2 Limestone, 3 3 Gneiss.

In structure this rock scarcely differs from granite. It is subject to disintegration, and suffers more from the action of atmospheric agents than granite. It has been maintained that

the limestones under consideration are metamorphic—the lower Silurian altered by heat. That this view is incorrect appears from the fact, that in St. Lawrence county the Potsdam sandstone actually overlies it. Fig. 9 represents a bluff of limestone and other primary rocks at Port Henry, in Essex county, New York, against which the Potsdam and calciferous sandrock reposes. The relation of these masses is far from being in accordance with the metamorphic doctrine.

Fig. 10.



a Limestone, *b* Hornblende.

Insulated masses of hornblende often occur in primary limestone. Sometimes they appear in quadrangular shapes, and in other cases their forms are irregular, as represented by fig. 10.

The same view of the origin of limestone is supported by the occurrence of it in hypersthene rock at Long pond, in Essex county. It is an oblong mass sixty feet wide, extending nearly north and south down the face of a precipitous ledge of rock. It is rich in pyroxene and scapolite.

The metals, their oxides or sulphurets, though not very common in this limestone, have usually run out, and like the granite associated with it, it has proved an unsafe rock for mining. There is one exception, however, in the franklinite and red oxide of zinc. The specular oxide of iron, which is common and very beautiful in St. Lawrence county, is often insulated and removed entirely from its bed; and it has been as yet impossible to recover the bed or vein when once lost.

The condition of the simple minerals in limestone is worthy of special notice. The phosphate of lime, though softened with difficulty in the flame of the common blowpipe, is apparently acted upon by heat; the edges and angles are rounded or flattened, as if it had been in a pasty state since it had assumed its prismatic form. The quartz, which is often imperfectly crystallized in its usual form, has its angles and edges rounded

also; but when in its most characteristic condition, it is more like a furnace slag than a crystal. Many pieces look as if while softened they had been drawn out or extended. Sometimes, again, the quartz has assumed a globular form, or the shape of a slag or of a bead. Notwithstanding, however, the similarity of the masses of quartz to furnace slag, it may not prove that those forms and conditions are due to heat; for globular quartz has been found in the calciferous sandrock, in which case it can not be referred to heat as a cause. Still, in the case of primary limestone, the circumstances are such as to favor the views I have expressed, and that the appearance of the masses referred to may be regarded as evidences of the fact.

Crystals imbedded in this rock often contain large particles of limestone in their interior. Pyroxene, quartz, phosphate of lime, and brown tourmalin are rarely free from this substance. The cavities containing the limestone are never angular, but always rounded. The imperfections of the crystals are due mainly to this cause. All the large crystals especially are subject to these faults, even the zircons, spinelles, and corundums are liable to them. I have noticed three districts in northern New York where this rock forms the most striking feature in the geology of each: 1. That of Jefferson and St. Lawrence counties, which has been already referred to; 2. Essex county, near lake Champlain, which may be traced, with very slight interruptions, into Warren county, forming a belt which runs northeast and southwest; and 3. Orange county. This last district extends into Sussex county, New Jersey, and forms a remarkable series of minor belts, which are prolonged to the southwest. In these three districts the limestone is very coarse and crystalline. Its true structure is like that of granite, and the lamination is generally obscure. Another and independent belt belongs to the Hoosick Mountain range. The beds crop out at intervals from Canada to Long Island sound. Their form is oblong, and the structure of the masses crystalline. They are in gneiss, and very frequently in close relation with hornblende. These beds are laminated, partaking of the structure

of the rocks to which they are subordinate. Another belt of the same character lies west of the Highlands, extending south through Orange county into Sussex county, New Jersey. In all these belts it is accompanied with serpentine, and in all these localities the rock is massive or only obscurely laminated. At Franklin furnace, franklinite and the red oxide of zinc are largely developed in this rock.

In Chester and Lancaster counties, Pennsylvania, this rock is very common. It contains serpentine, chondrodite, pyroxene, sphene, zircon, quartz, amphibole, corundum, graphite, &c. This rock is white crystalline, and contains carbonate of magnesia in many of the localities which have been cited. It lies in wedge-form masses, and disappears after being apparent at the surface for a few miles. It occurs in belts, whose direction is southwest and northeast.

Passing into Virginia, ranges of limestone skirt the eastern base of the Blue ridge, one of which passes through Albemarle county. They may be regarded as forming several subordinate belts between Lynchburg on the west, and the region of the marls on the east. They are composed of oblong or wedge-form masses, as in Pennsylvania. They are confined to the shistose and laminated rocks, as talcose and mica slate and hornblende. These beds are exposed to a much greater extent than at many other sections of the state, in consequence of the winding of the rivers which intersect the formations. In North Carolina the limestone rocks are extremely rare; two ranges, however, traverse the state from northeast to southwest. Beginning in Stokes county, it is found crossing the Yadkin, passing onward to Lincolnton in the direction of Kings mountain into South Carolina. Another belt belongs to the Blue ridge, and has been observed in Burke and Marion counties, Buncombe and Hayward counties.

The ranges of pyrocrystalline limestone which have been very briefly, and probably imperfectly, traced through Pennsylvania, Virginia, and North Carolina, belong to the laminated and schistose rocks; and they are less coarse and crystalline

than those of New Jersey and New York, which contain some of the rarer minerals, as zircon, sapphire, spinelle, and brucite. Still all these limestone beds must be regarded as belonging to the eruptive class. Those which are found in the first three states mentioned, resemble the beds in the Hoosick range, which pass through the eastern part of Berkshire and western part of Hampshire in Massachusetts. We should at any rate not confound them with the Vermont and Berkshire marbles, which belong clearly to the sedimentary series, and which are continuous and persistent through areas of great length. It is perhaps not easy to distinguish them in hand specimens, or in the cabinet, but their associations in the field attest the formation to which they belong. Geographical position often obscures the relations. For example, the beds of dolomite in Dalton and Washington are pyrocrystalline or primary limestones, while those of Pittsfield, only four miles to the west, belong to the Taconic system, or to the sedimentary class. The rocks can not be distinguished from each other by their lithological characters, and both are not unfrequently regarded as metamorphic; but the former stand in the same relation to metamorphism as granite and gneiss. The latter have no doubt undergone a change in their lithological characters, but it is not necessary to infer that the agent which induced the change was heat. Those geologists who refer all changes in structure and texture to heat, take only a partial view of the forces which act, and which have acted upon the earth's crust. A comprehensive view of the cause of structural change in rocks is of great value in geological reasoning, and we are thereby enabled to account for those changes when collateral facts forbid the agency of fire. The view which I have presented of the origin of those masses of limestone so common in St. Lawrence, Essex, and Orange counties, New York, in modified forms, two of which are prolonged into southern states, is consistent with known facts. 1. The position of many of these masses is such that they can not be referred to the lower Silurian limestones, as has been attempted by several eminent geologists. 2. From

the great extent of the sedimentary limestones it will follow that these must have been formed from preexisting limestones, which once belonged to the original constitution of the earth's crust. We must go back to their primary condition and position in the earth's crust. No one at the present day pretends that limestone is an organic product in the strict meaning of the word. Is it not better, then, when we find a limestone occupying those relations which forbid the adoption of the view that it is a changed rock, to place it with those masses with which it is associated? And such is the position and relation of all those masses of limestone which I have described under this head, that they can not be referred to the Silurian system without doing unnecessary violence to the relations which they naturally sustain.

SERPENTINE.

§ 65. It is green; the variety of shades being numerous, passing into black on one side, and on the other into very pale green. It is sometimes brown. Its grain is always fine, and in this respect there is a very great uniformity in all its varieties. It is never coarse like certain varieties of limestone, and if columnar, as at Lowell and Newfane, Vt., and Middlesex and Cummington, Mass., the individuals are extremely slender, passing into asbestus. The rock is homogeneous, and is both massive like granite, and laminated like gneiss, and hence belongs to both divisions of the pyrocrystalline rocks. The massive kinds occur at Lowell and Newfane, Vt., and Middlefield, Chester and Blanford, Mass.; or it may be it is sometimes obscurely laminated. The distinctly laminated kind in Macon county, N. C., is of a dark green, where its lamination is more distinct than that of gneiss. The same variety is found at or near Port Henry, Essex co., N. Y. In Middlefield and Chester, it forms a range of hills some five or six miles in length, and less than half a mile in breadth. The serpentine of the Bare hills, near Baltimore, resembles that of Chester, and is probably more extensive. This rock is remarkably distinct from

other rocks; it passes into steatite, but very rarely, if ever, into other rocks. The evidence of its igneous origin is less than that of primary limestone. I have never seen it in narrow veins and dykes like greenstone, neither does it occur resting upon other rocks. It rather appears to have been protruded between other rocks, as at Middlefield, where on one side it is bounded by hornblende, and on the other by mica slate. Chromite of iron, with many varieties of chalcedony and jasper, are among its associates. All the localities which I have named, furnish it. The serpentine of Troy, Vt., near the Provincial line, is traversed by a wedge-form vein of magnetic iron. Like primary limestone, it is an unsafe rock for mining.

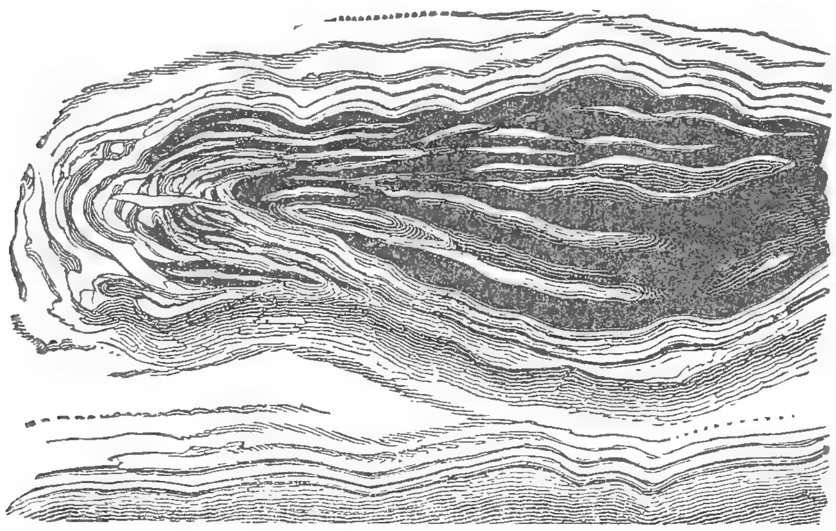
Serpentine, when largely mixed with limestone, does not contain chromite of iron. It appears to be absent in the calcareo-serpentines of Canada, the St. Lawrence and Champlain districts, and I believe also in Sussex, N. J., and Orange county, N. Y. Mica and talc, however, in crystals, are common. Large plates of bronze-colored mica occur in the serpentine of Gouverneur, N. Y., and hexahedral tables of a deep green talc at Troy, Vt., associated with arragonite, and octahedral iron with brilliant faces.

The occurrence of so large a quantity of silicious minerals not unlike silicious sinter, furnishes some evidence that beds of serpentine may have been connected with ancient hot springs. Macon county, N. C., especially furnishes immense quantities of sinter-like deposit, in connection with serpentine.

Serpentine is one of the constant associates of this kind of limestone, in New York, Canada West, and New Jersey. It is frequently disseminated through it in small grains, but sometimes in large masses of an irregular form and rough surface, and again in fibrous masses. The grains and masses stand out in relief, the limestone weathering more rapidly than the serpentine. This mixed or compound rock, takes a very good polish, and might be used for a variety of purposes when the rock is sound. The serpentine is arranged in the form of coarse

agatized bands, with a shape more oval than round, as in fig. 12.

Fig. 12.



When serpentine is intermixed with limestone, it is often rich in other minerals. The primary limestone, though mixed with serpentine, is frequently pure; sometimes it is magnesian. That of Jefferson county is composed of

Carbonate of lime,	98·24
Alumina and peroxide of iron,	0·88
Silica,	0·88

The defects of this serpentine limestone, arise from an intermixture of silica, pyroxene, and hornblende, which appear in masses disseminated through it.

A serpentine of a pattern somewhat different from the foregoing, occurs in the state of Connecticut, at Milford. It has been described in the Geological Report of that state, by Mr. Percival, as a serpentine marble. It consists of two short ranges; the one includes the New Haven quarries, and the other the Milford. The rock is remarkably fine-grained, and is distinguished for the beauty of its variegated colors; blue, green and yellowish green predominating. Pyroxene, epidote, magnetic iron, picrolite, and chromic iron, are associated with it.

The serpentine marble of Milford and New Haven, is more intimately blended with the limestone than that of northern

New York and the British provinces, clouding, as it were, the mass, while in the latter places it is in distinct grains and masses, which are perfectly circumscribed, and may be detached by a blow, when aided by previous decomposition.

The serpentines of St. Lawrence county, and which are often associated with the earthy oxides of iron, contain angular pieces of quartz, from a tenth to half an inch in diameter; the quartz is not incorporated with the rock, yet it is closely invested with serpentine, and is perfectly separated from it by disintegration.

The serpentine of Cornwall, Eng., is associated with diallage rock, and is traversed by veins of this substance, as well as by granite. Our serpentines very rarely contain diallage. The dark green serpentine of Westfield, Mass., contains schiller spar. It appears then that it is traversed by other rocks, but I have not seen that the different geological writers have observed serpentine traversing in this mode, other rocks, except in Tuscany. Yet it may have been observed, at many other places, but regarded as not worthy of attention.

In the serpentine belt of Port Henry, the mixtures of serpentine and other minerals decompose and leave a scoriaceous mass, like calcareous tufa, as if there was first a deposit or formation of a very porous mass, which was afterwards filled by infiltration with carbonate of lime. I know of no true serpentine so connected with sedimentary rocks as to give a clue to its age, excepting that associated with the waterlime near Syracuse. In St. Lawrence county, iron ore and serpentine are somewhat blended with the Potsdam sandstone. As it occurs in this country, it must be regarded as one of the most ancient of our rocks. The specific gravity of this mineral is 2·55.

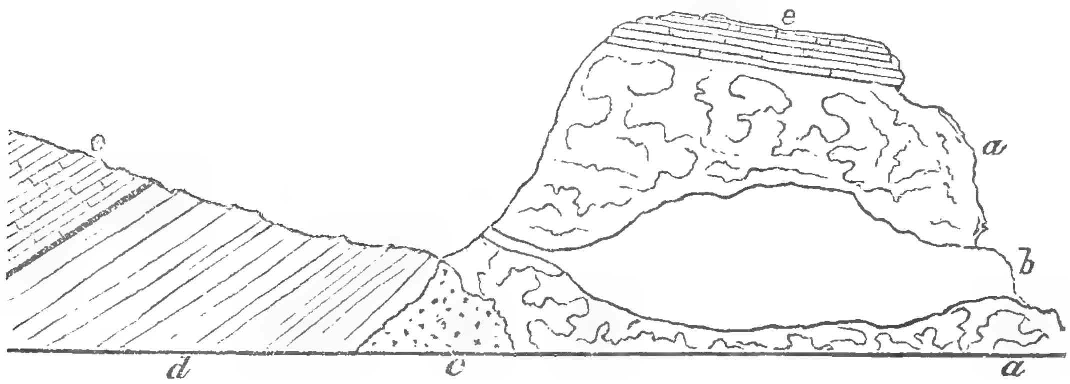
Serpentine is a hydrous bisilicate of magnesia. It is composed of

Silica,	41·89
Magnesia,	40·24
Oxide of iron,	3·38
Water,	15·20

Serpentine, though it can not be regarded in itself as rich in ores, yet it is often associated with, or rather in near contiguity to a great variety of minerals. Chromic iron is one of its most constant associates, and occasionally magnetic iron traverses it in veins, as at Troy, Vt., and in some parts of Europe, it is rich in copper. In St. Lawrence county, N. Y., all the beds and veins of specular iron are contiguous to serpentine, and this is the case also with the large rocks of magnetic iron in the Adirondack, in Essex county.

At the well known Parrish mine in St. Lawrence county, N. Y., the serpentine is protruded beneath the gneiss and specular

Fig. 13.



iron, as represented in fig. 13, thus: *a a* is a mass of ore, rather silicious, *b* an adit in the mass of ore, *c* protruded serpentine, *d* gneiss, and *e e* Potsdam sandstone. The serpentine in this instance, seems to have been the rock of eruption which elevated and broke up the sandstone. So also in a contiguous vein known as the Kearney ore bed, a similar dislocation is known. Near Theresa the relations of the rocks are the same, of which fig. 15 is a section: *a* serpentine, *b b* specular iron ore. Instances of the same kind and character might be multiplied.

Fig. 14.

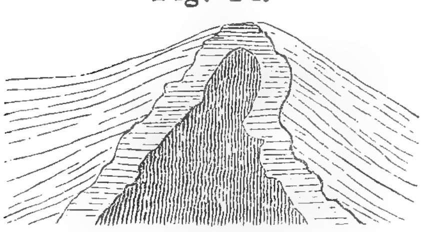


Fig. 14.—Limestone intermixed with serpentine, appears in the gneiss on the east side of the harbor at Whitehall. It has disturbed the superincumbent Potsdam sandstone.

The facts revealed by the relations of the associated rocks,

Fig. 15.

a Serpentine, *b b* Specular Iron Ore.

support the view that surpentine is truly an eruptive rock, and belongs to the same class as granite and sienite. This view is also sustained by its distribution and mode of its occurrence, the latter of which has been spoken of. Its distribution is more or less in belts or lines, whose directions are well indicated when we compare the position and relations of the masses at distant points. This will appear on comparison of the distribution of the rock along the Green Mountain range. Beginning at the extreme northern boundary of Vermont, in the township of Troy, and following its range south, we shall find its masses distributed along a north and south line. From Troy it extends into Canada East, but southerly it is met with at Lowell, Newfane, Vt., Windsor, Middlefield, Chester, Blandford, Mass., and finally on nearly the same range as the Milford and New Haven quarries in Connecticut. The serpentine of this belt is alike. That of Milford and New Haven is more calcareous, and its colors are lighter and more blended with yellows than at the northern localities. The belt is also chromiferous, and more or less ferriferous. If the Green mountains should be regarded as a part of the Highlands, and as a prolongation of the Alleganies, we shall find the serpentine arranged in a northeast and southwest line, forming a belt of this rock along the whole eastern slope of this range of mountains, as far south as Georgia. It is coextensive with the Blue ridge, and is chromiferous through its entire extent.

I have already spoken of the fields of serpentine associated with the pyrocrystalline limestone of Warren, Essex, Jefferson, St. Lawrence and Orange counties, N. Y.; to which may be added that of the district of Johnstown in Canada West. These

districts or fields of serpentine differ from that which belongs to the Green or Hoosick Mountain and Allegany ranges. Pyroxenenas, amphiboles and graphite, are common to the former, but very rare in the latter; that is if they occur in proximity, they belong rather to other rocks, and not to the serpentine. The silicious minerals, as chalcedony, chrysoprase and agates, are associated with the former ranges, to which may be added from the magnesian minerals, schiller spar. In Maine, Dr. Jackson mentions only one locality of serpentine, that of Deer island, which seems to have been erupted through granite. This mass may be connected with that of the Grand Menan, on the northern coast of Maine and Nova Scotia.

Serpentine is extensively developed in Pennsylvania, Virginia, and Maryland. I may cite the serpentine rock of the Pine Barren range. It extends from East Nottingham into Maryland, after crossing the Northeast creek. It contains chrome ore. It belongs to the Chester and Lancaster county belt. It contains also silicate of magnesia, a mineral which is worth some three or four dollars per ton. This belt continues onward west by south into Harford county, Maryland, crossing the Susquehanna near Fraser's Point. The belt is prolonged to the southwest, embracing the Bare hills near Baltimore. Its continuity is interrupted in many places, still the belt extends through Pennsylvania into New Jersey in the direction of Easton, Northampton county. It is rather remarkable that serpentine, though it forms by itself hills of a moderate elevation, yet does not appear in the higher parts of the Appalachians. It is highly chromiferous through Maryland. In North Carolina, in those counties which are adjacent to Virginia, it is not so common as in the more northern states. It reappears, however, in great force in the southwest, particularly in Franklin, Macon, and Cherokee counties. The same belt extends into Georgia. Of this rock, then, it may be said to extend from Canada to Georgia in a belt which skirts the eastern base of the Hoosick and Appalachian chains. In the Appalachians its direction is nearly northeast and southwest; in the Hoosick range nearly

north and south. The external characters are very uniform through the whole distance, and it is very constantly associated with certain minerals. These have been already referred to. Certain minerals, too, are as constantly absent, as galena, the sulphurets of copper, iron, molybdena, and zinc.

Notwithstanding the wide range of serpentine in this country, it occurs so rarely among the rocks of sedimentary origin that its age, even approximately, is left undetermined, in which respect it is in the same condition as the granites. In St. Lawrence and Jefferson counties, New York, the serpentine has evidently disturbed the Potsdam sandstone in numerous places, and it seems highly probable that both the serpentine and pyrocrystalline limestones were erupted subsequent to the commencement of the Silurian epoch. There is another instance of the occurrence of serpentine of a still later date: it is near the epoch of the consolidation of the waterlimes. The locality is in the vicinity of Syracuse, Onondaga county, New York. Here it is evidently a serpentine of contact, or a metamorphic serpentine. Those magnesian rocks are altered or changed into serpentine by proximity with some eruptive rock. The changes are variable. Some portions of the rock are perfect serpentines, passing into masses which are only slightly altered; and in a few cases the change has been still greater, as appears from the production of mica, forming a mass somewhat similar to granite. These altered rocks are confined to a small area. Like granite, therefore, it appears that serpentine has been the product of different periods, and to have been the product of agencies which have operated in a manner similar to those which gave origin to granitic compounds. But it appears that it is possible only in a few instances to determine the time of its eruption, in consequence of its being so rarely connected in this country with rocks of a determined epoch.

RENSSELAERITE.

§ 66. This rock has been regarded by a few of our geologists as a pyroxenic steatite. It is however perfectly homogeneous, and when the circumstances were favorable for crystalization, it is traversed by distinct joints, by which it is clearly a cleavable substance in the mass. Its hardness is 3·5–4, and hence is greater than steatite and less than pyroxene; its specific gravity is 2·874. It is composed of

Silica,	59·75
Magnesia,	32·90
Lime,	1·00
Peroxide of iron,	3·40
Water,	2·85

It resembles serpentine in the structure of the mass, but its particles of composition are coarser and more crystalline. It is white or grayish white, and tinged faintly with green. Black varieties are not uncommon. It is traversed by irregular seams of satinspar, disposed without order. It is massive, and its lamination is obscurely brought out by weathering. Exposure to the air softens, and heating it to redness slightly hardens and whitens it. It is cracked by the same exposure. The rock is tough and difficult to break. It occurs in many large beds in St. Lawrence county in the township of Russell, New York. It is also distributed in smaller fields in Jefferson and Lewis counties. It accompanies the limestone and serpentines of that district, and may be readily distinguished from the latter by its hardness. In the absence of iron, chrome, chalcedony, and the jaspery varieties of quartz, we may observe that it is unlike serpentine in its associations; still, as a mass, and in its position, it agrees with serpentine. It is not generally distributed in this country.

Rensselaerite takes a very good polish, but less so than serpentine. Its texture and grain is even, and being easily wrought, especially that part of the rock which has been

exposed to the weather, it has been cut into a variety of useful articles, as candlesticks, inkstands, &c. The form of the crystal can not be distinguished from pyroxene, but the faces being too dull to admit of the use of the reflecting geniometer, it may still differ from it in its dimensions.

As a mineral, it was regarded by the late Prof. L. C. Beck as a mixed mineral, consisting of steatite and pyroxene. This view is apparently sustained by Beudant, who obtained from Sahla steatitic pyroxene swhich retained the form and cleavage of pyroxene. But contrary to this doctrine, it may be said that the mineral is perfectly homogeneous, at least as much so as serpentine, limestone, or any other mineral or rock usually regarded as simple. No foreign matter can be detected by the microscope, either in the form of plates, amorphous or crystalline grains. It is not uncommon to find hornblende and pyroxene combined in distinct crystalline particles, which together make up a crystal of the form of pyroxene. In this case the mixed nature of the mineral is evident to the senses, and it is as easy to refer each to the proper species, as it is the particles composing a mass of granite. I see no reason why we should assume a mineral to be mixed of two or more minerals in the absence of all external evidence. There is no objection, however, to receiving this mass into our list of rocks, although it may be found hereafter to be confined to the northern part of New York.

OCTAHEDRAL AND RHOMBOHEDRAL IRON ROCK.

§ 67. The largest bodies of magnetic or octahedral iron ore known in this country are subordinate to the hypersthene rock in the Adirondack group of mountains in the western part of Essex county, New York. The iron rock has a jointed structure, or it is traversed by divisional planes which bound large tabular masses. It is interlaminated with masses of this rock, and in some instances seems to disappear beneath it. At Adirondack one of the bodies of iron ore is between 700 and 800 feet thick. It disappears beneath the rock, and its actual

limits are unknown. The degree of oxidation of the particles composing the masses of this ore seem to be unequal, and hence there is more difficulty than usual attending its reduction.

This species of iron in northern New York, the Highlands, and New Jersey, is associated with quartz, hornblende, and feldspar; and two very extensive bodies of ore are intermixed almost exclusively with phosphate of lime. But the magnetic oxide is usually grouped with one of the three first named. Quartz is the most favorable rock for reduction, in an economical point of view. The specific gravity of octahedral iron is 5·09; the rocks which are grouped with it scarcely exceed 3·00. If, then, these minerals were fused together, the iron, from its greater specific gravity, would sink through the molten mass, and be found at a lower level. In the majority of mines of this ore, the leanest part is at the surface. Particles of ore are scattered sparsely through the rock at the outcrop of the vein; but at the depth of twenty feet, and perhaps less than twenty, there is a perceptible increase of metal. The gravity of the iron ores may therefore explain the fact of their comparative absence as a rock at the surface; and it may be reasonably inferred from this and other facts, that the veins of ore are connected with much larger masses beneath than any which have found their way to the surface. Serpentine is very common among the beds and veins of this ore in northern New York. It is not in large masses, neither have I always found it in the beds of octahedral iron. It also accompanies the specular oxide of iron in St. Lawrence county, New York.

The great extent of iron ores of these two species, the magnetic and specular oxides of iron, seem to require that, in this country at least, they should be embraced in the rocks. They have hitherto been described as minerals only; but as they occur in mountain masses, occupying positions analogous to to serpentines, limestones, and granites, there can be no objection to ranking them with the subordinate rocks of the globe.

Magnetic iron occurs in masses and veins. In the hypersthene rock it is in masses subordinate to that rock, while in the gneiss

of Essex and Orange counties, New York, it is in veins. The magnetic iron district of New York begins just north of the valley of the Mohawk, and occurs in all the counties in that part of the state, the veins themselves occurring in subordinate or smaller districts; or, in other words, veins of this ore appear to cluster together in certain areas, as it is rare that a single vein is found occupying a district: where one vein is found, it is usual to find several running in parallel lines. The specular ore occupies two or more districts in Jefferson and St. Lawrence counties. These are usually associated with serpentine or pyrocrystalline limestone. Magnetic and specular iron ores are composed of

	Magnetic oxide.	Specular oxide.
Oxygen,	28·21	30·66
Metallic iron,	71·79	69·34

Both species are variable in composition from foreign matter, particularly quartz. The special relations of the two species of iron ore will be given in the part relating to mining.

I have given the direction of the ranges or belts of the pyrocrystalline limestone and serpentine; and it is discovered that these two rocks skirt the eastern base of the Appalachians through their entire length from northeast to southwest. The same fact may be stated respecting the range of the octahedral iron in Orange county, adjacent to the Highlands. Among this cluster of mines I may enumerate some seven or eight extensive formations, among which are the Long, Rich, Forchee, and Wilkes mines. The formation which carries the magnetic iron passes into and through the state of New Jersey from the Sterling mines to those of Pompton, of which there are some three or four veins which are included in a gneiss abounding in hornblende—a rock which is quite massive, and is sometimes called, from its resemblance to granite, a gneissoid granite. A cluster of many veins are known, and have been worked, in the neighborhood of Dover. This seems to be a distinct belt, and pursues a southwesterly course towards the Delaware. A parallel belt more westerly is also known, and which embraces the zinc-

iron ores which lie in a line, passing very nearly through the range of Scott's mountain towards Phillipsburg, opposite to Easton, on the southwest side of the Delaware. The belts of iron ore which pass from the southern Highlands of New York through New Jersey into Pennsylvania, might be described more particularly, and as running in at least three parallel belts. But it is my object at this time to speak generally of the relation of this ore or rock to the low ranges of mountain chains, which may be called outliers of the Appalachians, and which, taken as a whole, constitute one great belt of iron rock coextensive with the great mountain ranges of the Atlantic slope.

The magnetic ores of Pennsylvania are confined to the southeastern part of the state. They are quite limited in extent when compared with the great development in New York and New Jersey. The few veins which do occur, however, lie in the same ranges as those of the states just named. Thus in Burke county there are several parallel veins at mount Pleasant. At Durham, on the Delaware, is another district of this ore.

In Virginia, the ores of iron are abundant in the eastern section of the state, extending from a little south of Fredericksburg to Carolina; but it is an interesting fact, that most of the beds and veins have been changed into the hydrous brown oxides. They occupy the same relative position as the magnetic ores. A southwest range, however, of magnetic ores passes through Buckingham, Patrick, and Franklin counties, following closely the Blue ridge in its southwestern prolongation.

In North Carolina the iron ores, skirting the subordinate ranges of the Blue ridge, are equally abundant; but they follow two or three lines, one of which passes through Granville, Orange, Guilford, and Chatham counties; another west of the Blue ridge, through Ash, Yancey, and Buncombe and Cherokee into Georgia. The condition of the ores, however, is much the same as in Virginia, the magnetic having been changed to the hydrous brown oxide. From the foregoing it appears that

all that part of the United States which lies east of and upon the Appalachians, is supplied most abundantly with this valuable ore of iron. It skirts this great range for more than a thousand miles; and though not by any means continuous, still it occurs at convenient intervals, and at such points as can not fail to supply the wants of over six millions of inhabitants.

OF THE LAMINATED PYROCRYSTALLINE ROCKS.

§ 68. *Lamination and cleavage planes.* Much has been said with a view to elucidate the efficient cause which has operated in the production of planes of lamination, or planes of cleavage. A phenomenon which is universal, is not to be attributed to local influences. Local influences are adjurants, but not the efficients of change. The wide-spread derivative matter, on the ocean's bottom, consisting of fine sand, clays and lime, mingled together, are a mere mechanical mixture, mingled together without order. But it is found that slates which are the results of such mixtures, have undergone, in process of time, very great changes. But the rocks referred to slates, differ much in the amount of change which they have suffered. Some are hard and ringing, others soft and fragile. Those which belong to the first, do not usually occupy their original position, but they are inclined, and appear to have been acted upon by mechanical forces, to a much greater extent than the latter. Pressure, therefore, must be recognized as a force which has had something to do in converting them into hard and firm slates, and in developing the peculiar structures of slaty masses. But pressure is an adjurant to an efficient cause, and this efficient cause must be referred to some of the essential properties of matter or to original endowments. This original endowment is probably crystallization. I have had occasion to speak of this property before. I have also employed the term, molecular force, a term which I have used where the result is the formation of spheroids, or rather nodular masses, while crystallization produces parallelograms upon a large scale. In the formation of the planes of parallelograms, pressure aids the

efficient force by bringing the particles near to each other. Pressure unaided by this force, is insufficient to develop planes of any kind.

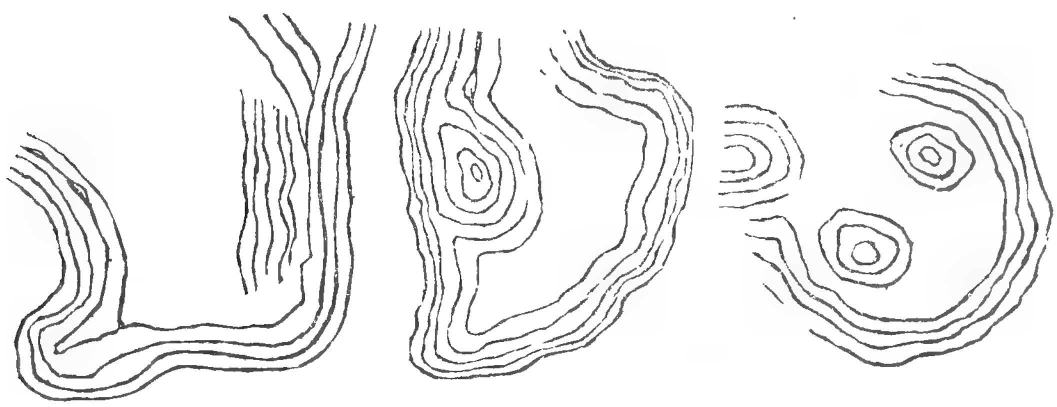
The production of the planes of cleavage, or lamination, has been attributed, by Prof. H. D. Rodgers, to an electro-galvanic or electro-thermal agency. This, to be sure, must be regarded as one of the universal properties of matter, or a force made sensible through the medium of matter. The theoretical explanation is founded on the supposition that the slate planes, after flexure, are alternately hot and cold, and hence are the generaters of an electrial power analogous to that of the thermo-electric pile. It is difficult, however, to understand how these arrangements operate in the production of planes; moreover, it requires the preexistence of planes of some kind, in order that the analogies may be made out. It seems, that in this explanation the effect preceded the cause. If each molecule of matter has polarity, all we have to do to secure a symmetrical arrangement is, to bring the particles composing a rock within the sphere of each other's attraction. Adjustments will then take place. Compression or pressure operates in this way.

The existence of planes of lamination or cleavage in gneiss, mica slate, etc., receives an explanation at least partly from the foregoing principles. The efficient cause may be stated in different words. We may recognize the polarity of the molecules of matter, or we may use the word crystallization, and in some cases molecular forces; for in the use of the latter term, it seems we recognize a greater change of the particles in space, even entire strata are formed by this force. Concretions, too, are gathered or formed from similar particles, and from comparatively wide spaces; where the matter is insufficient to form a stratum, for in the mass of mud which ultimately forms slate, the lime and silex were intermingled without order; but now we find the lime in nodular bands, or distinct nodules, as in septaria, which could not have been in that state in the original deposition. We call it then a concretionary or mole-

cular force from the effects produced; it is a modified crystalline force.

In sandstones and limestones molecular movements often obliterate the planes of stratification or deposition. These movements result in the formation of spheroids, or the forms represented in fig. 17; a general illustration of the kind of molecular movement, which may be observed in many sedimentary rocks, and also in rocks of igneous origin, as serpentine.

Fig. 17.



We may recognize, too, in this phenomenon, one of the efficient causes of metamorphism, a cause which whenever the spaces between the particles of a mass are charged with water, or possess from any other cause a partial fluidity, is free to operate.

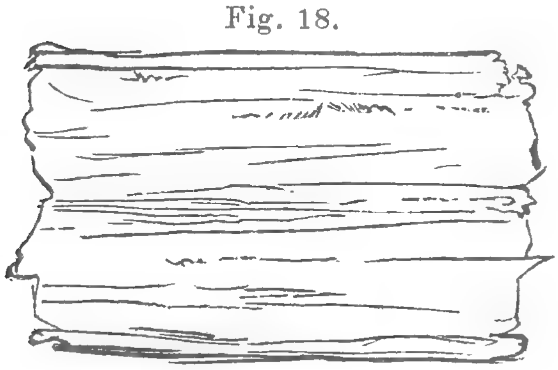
The importance of recognizing the essential properties of matter as efficient causes of change in rocks, it seems to me has not been perceived, and hence has not been investigated so fully as it should be. Having stated the foregoing views respecting cleavage planes or lamination, I proceed to speak of the characters of the laminated rocks, gneiss, mica slate, &c.

§ 69. *Gneiss.* The rocks of this class, in whatever part of the globe they occur, are all alike and undistinguishable. A mass of gneiss from the Alps or Pyrenees, can not be distinguished from a mass from the Alleghanies. The mica slate of the Alleghanies differs, in no respect, from the mica slate of the Rocky mountains. The same remarks may be extended to granite, sienite, and indeed to all the eruptive rocks. Fire has left the same impress upon all of them, in all quarters of the

globe where they occur. In this class of rocks there is no order of superposition. In some districts gneiss may occupy a position contiguous to granite; in other districts mica slate may occupy the same position relative to granite, and gneiss may appear in many instances overlying hornblende rock, talcose or mica slate. The Hoosick Mountain and the Appallachian ranges, furnish many examples of the varied and variable collocations of these rocks. They may, therefore, be said to belong to one epoch.

It has been stated, already, that gneiss differs from granite in its structure. Its particles are structurally parallel. Fig. 18 represents this structure. This parallelism has been regarded, by distinguished geologists, as due to water. Of this statement more evidence is required: indeed when we consider the extent of the change required to convert any sediment into gneiss or mica slate by heat, and over such wide areas, we can scarcely fail to feel that the origin assigned is at least extremely doubtful, especially when it is considered that the crust had already cooled so much as to admit of the condensation of water upon it, and the formation of oceans in all quarters of the globe. While the metamorphic view is regarded as inapplicable to this class of rocks over wide-spread fields the world over, I do not call in question those instances of local metamorphisms which occur in the Alps and other districts, where it is evident the disturbances and changes by heat are very remarkable. But who has observed in this country, sandstones, conglomorates, slates, and limestones, which have been converted into gneiss and mica slate, or hornblende rock. It is true rocks are altered. Chalk has been changed into a hard crystalline marble, but the area over which this change can be traced, is quite limited. Clay, too, has been baked, and under that process has become hard, and firm enough

Fig. 18.



to ring like metal when struck with a hard body; but it has not become gneiss or hornblende. The extent of all the individual rocks under consideration; together with their identity of structure the world over, is to say the least, indicative of their early consolidation, and that it took place at a period when water existed only in a vaporous state.

These remarks, it will be perceived, apply to this country. The metamorphic gneiss of the Alps is admitted by eminent geologists. It is, of coarse, local, and we can not set bounds to extent of local changes. Still the metamorphic gneiss of the Alps originating in oolite and eocine rocks, must furnish by analysis, a difference in the proportion of their elements from that which exists in our normal gneiss or mica slate. It is now admitted that a parallel structure of itself is no evidence that the rock was a sediment. I pointed out, in my New York Geological Reports, that the porphyry of lake Champlain was laminated, and described it as stratified rock, notwithstanding the indubitable evidence it furnishes at the locality, that it was erupted from fissures in the shales of the Hudson River group. Darwin describes an eruptive red granite of Chili, which exhibits a decided parallel structure in many of its parts. The gneiss of Bahia, according to the same author, contains regular fragments of hornblende; hence gneiss may be regarded as a pyrocrystalline or eruptive rock, at many localities. We should subject the question of metamorphism to two tests: 1. Proximity to agencies competent to effect the change observed. 2. The continuity of the changed to the unchanged mass.

The only proof, therefore, which we can obtain, of metamorphism, is in the local change which may have been produced in a part of the rock. There will then be gradations, which may be traceable from zones of the greatest to zones of the least change. We may trace the harder, ringing, reddened, or whitened mass, to those parts which retain their original properties. Beyond this we can not go. To this extent it is useful to admit the metamorphic theory.

Gneiss is somewhat variable in structure and composition.

In structure it approaches granite in many districts in the United States. In composition the mica may be wholly or in part replaced by hornblende, and a part of the feldspar of the rock crystallized in large particles. We have then the granitoid gneiss, hornblendic and porphyritic gneiss. If mica abounds in it, it is either said to be schistose or micaceous gneiss; or if quartz, quartzose gneiss. These terms are employed to express its structure or composition in any observed locality. Gneiss passes into mica slate by the loss of its feldspar.

The foregoing considerations seem to establish the doctrine that gneiss, mica slate, hornblende and talcose slate are really contemporaneous formations. They are so blended in all the districts of our country, that it is extremely difficult, if not impossible, to define their boundaries. Even in the talcose slate of the gold region, gneiss frequently appears in wide areas. I shall not attempt, therefore, to give the boundaries or extent of either of the foregoing rocks, being content with pointing out the regions they occupy in common.

§ 70. *Mica slate.* This rock consists of mica and quartz. The laminæ are thinner than those of gneiss, and it has more mica in its composition. The feldspar, when it occurs in this rock, is in the form of seams or segregation, intermixed with a coarser mica than that which composes the body of the rock. The quartz is gray, the mica usually black, and the particles of both are fine.

Numerous varieties might be pointed out, which are due to variable proportions of quartz and mica, or to the thickness of the laminæ, or to the intermixture of other minerals, as hornblende or talc. These varieties are not so important as to require detailed descriptions. It is sufficient that the student should know that mica slate passes lithologically into other rocks without changing materially its structure.

§ 71. *Talcose slate.* It is composed of talc and quartz. Its laminæ are thinner than those of mica slate. Its color is gray, and its luster is more silken than mica slate. Its laminæ are undulating, curled, or crisped. Its texture is fine, and its feel

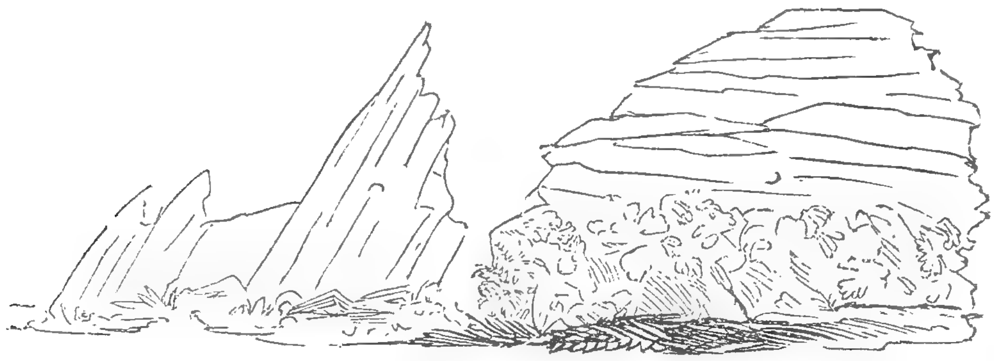
soft. Varieties occur in which the quartz is the principal mineral, and its structure then resembles a fine-grained sandstone. On the other hand, when talc predominates it becomes steatitic or a perfect steatite. Mixed largely with scales of mica, it becomes a talco-micaceous slate. Like other rocks of this epoch, it passes into one or the other mineralogical mass, with the necessary exchange or substitution of the mineral which characterizes them. It is associated with hornblende rather than mica slate.

§ 72. *Hornblende rock.* Its color is green, light green, or blackish green, and its composition is either an unmixed hornblende, or else it is mixed with feldspar and quartz, the particles of each being arranged in parallel bands. In this last particular it differs from sienite. Hornblende is exceedingly tough, and the mineral is always crystalline. The crystals are interlaced with each other. Its composition is variable. It preserves, however, a great uniformity of character when associated with other laminated pyrocrystalline rocks; it is more variable in a trapean region.

The laminated pyrocrystalline rocks lie in proximity to each other. It is rare for a mountain to be composed exclusively of one of these rocks, and it frequently happens that gneiss, mica slate, and hornblende form an alternating series, in which they are separated by short distances only. On the sides of mountains, and in valleys, their planes of lamination incline steeply to the horizon, while perhaps upon the crests of high ridges the laminæ are nearly horizontal. This seems due to an upward thrust, by which the upper parts of the rock being unsupported, fall into an horizontal position. At the point of flexure the mass is frequently broken, when the lower portion of the rock is left highly inclined to the horizon, and the broken part is nearly prostrate. Such is the position of the talcose slate of Table mountain in Burke county, North Carolina (fig. 19). The body of the mountain is composed of strata highly inclined to the west, but the summit is quite flat. The porphyritic gneiss of the Swannanoegap of the Blue ridge, in North Carolina, is

quite flat upon the crest, but quite steep at the base. But in the mountains of New England the laminæ are steep to the summits. Probably diluvial action has swept off those flattened crests which exist in the southern states.

Fig. 19.



§ 73. *Chlorite slate* is a green fissile, or slaty rock, with a soft feel. In order to make out this rock, it is necessary to recognize chlorite intermixed with quartz, and a structure similar to talcose slate. It may contain feldspar and mica. It is often associated with gneiss and other schistose rocks. The specific gravity of chlorite is 2·72. Its composition is subjoined:

Silica,	26·0
Magnesia,	8·0
Oxide of iron,	43·0
Alumina,	18·5
Water,	2·0
Potash,	2·0

§ 74. *Clay slate.* This rock is a hardened clay or shale, and is for the most part exceeding fissile. Its colors are green, bluish green, and reddish or brown and purple. The red colors are variable, from a pink red to a deep brick red. The laminæ are distinct.

It is doubtful whether clay slate should be admitted as a member of the pyrocrystalline rocks. I should not regard it as an eruptive rock, and place it in this connection, were it not generally placed among the primary rocks, and were it not also quite common in proximity with veins in granite in North Carolina and other places. It is, however, possible that this

variety of slate rock, which passes for clay slate, may be a variety of chlorite slate. Neither the mineralogist, geologist, or miner, has regarded the inquiries relative to the composition of rocks, veinstones, &c., of much importance, and hence they have been neglected.

§ 75. *Laminated limestone and serpentine.* Where limestone and serpentine are associated with gneiss and mica slate, they exhibit a parallel structure. They have been acted upon by forces of the same kind and nature. We are not obliged to adopt the opinion that limestone and serpentine are metamorphic when we can detect a parallel structure. The facts in each particular locality must speak for us. For a full notice of this rock I refer the reader to § 65, the serpentine marbles.

§ 76. *Quartzite.* I apply this term to a massive rock associated with the auriferous slates. It is smoke gray, light or dark, breaking with a conchoidal fracture, and hence resembles flint or hornstone. It appears to be a simple substance; but it becomes white by weathering, and hence it is probably compound. The quartzite contains sulphuret of iron, which may be auriferous. Some varieties are agatized coarsely. There is considerable evidence that the rocks associated with it are stratified, and hence it may be ranked among the metamorphic products. This question must remain open for further observation.

DISTRIBUTION OF THE PYROCRYSTALLINE ROCKS.

§ 77. The pyrocrystalline rocks are blended and interlaminated so frequently in every district of the United States, that it is impracticable at present to trace either of them separately through the range of country which they occupy. The White mountains in New Hampshire, mount Ktaddin, Maine; Monadnock, New Hampshire; Hoosick mountain and Black mountain, and the culminating point of the Appalachians, are gneiss and mica slate. Many of the passes over the Blue ridge in North Carolina and Virginia, are talcose slate; Pilot mountain in Stokes, and Table rock in Burke counties, are talcose slates;

but still they are associated with gneiss and hornblende in the vicinity. A long list of localities might be made out of the kinds of rock prevailing at different points in the Union; but it is impossible to show, at the present time, that there exist important relations between any two distant points. At the most distant points of our country these rocks preserve a great similarity of structure and of character, which renders it impossible to recognize by specimen the part of the country they represent. They are traversed also by granitic veins, the composition of which exhibits everywhere the same variations. There are districts, however, in which trap is much more abundant than in others; and these districts furnish us with a greater remove from the common character of the country at large. I shall speak of the peculiar rocks of certain districts when I have occasion to take up the subject of mines and mining.

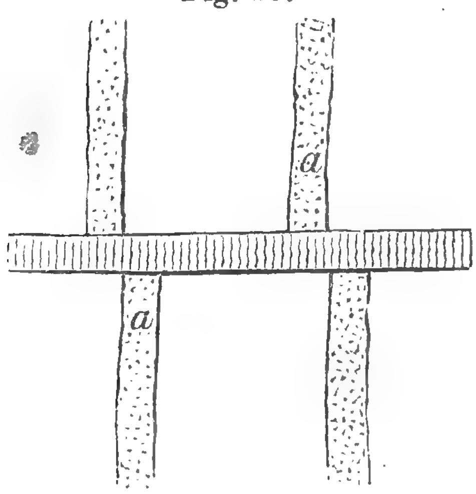
PYROPLASTIC ROCKS.

§ 78. The first section embraces those rocks which are supposed to have been erupted through fissures in a molten state, and to have cooled beneath the ocean, and hence I have denominated them *submarine.* The greenstones amygdaloids, basalts, traps and porphyries, are comprehended in the section. The second section embraces those which have been erupted from craters, and have cooled in the open air, and hence I have called them *subærial.* They embrace the modern lavas, of all kinds: the vesicular lava, obsidian, volcanic arks, &c.

1. *Submarine.*—The rocks of this section are lithologically the same as in all parts of the globe. A traveler who speaks of trap in the greenstone or basalts of Australia, is understood by us in America. The greenstones of the Hudson river scarcely differ from those of Connecticut or Nova Scotia. Greenstone is massive, vesicular, columnar, and porphyritic. The first is a heavy black or grayish black rock, either occupying fissures in other rocks, or lying upon them, having been forced out from beneath in a molten state, and in a condition to overflow the region adjacent to the fissures. The term trap seems to be re-

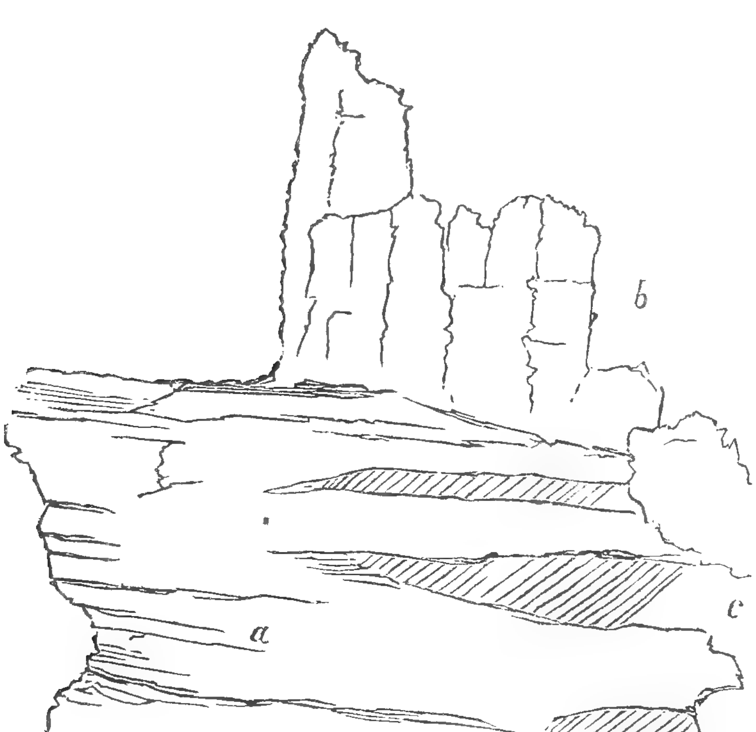
stricted to that form of greenstone which is inclosed within the veins of a fissure. It is commonly called a trap dyke. It is a stony and not a metalliferous vein. Fig. 20 represents a dyke

Fig. 20.



intersecting two parallel veins of granite. The forms of the pyroplastic rocks were determined by the condition under which they cooled. We can not always determine now what that condition was. It has been demonstrated that slow cooling restores to the mass the common characters of a rock, free from vitrification. So under certain circumstances the mass separates into columns of five or six sides. The tendency to the columnar condition is distinct, while the columns are often imperfect. Their terminal outline is visible, but the adhesion of their sides still remains. The columns are vertical, as at the Palisades of the Hudson, or they may be horizontal, as when enclosed between the walls of a fissure.

Fig. 21.



a Sandstone, *b* Columnar Trap, *c* Trap injected between the strata of sandstone.

Fig. 21 represents the rude columnar structure of the Palisades, which repose upon the lower members of the trias. The molten mass was also injected between the strata of sandstone. Greenstone is sometimes vesicular, but the vesicles having been filled with foreign substances, and remaining in relief after the rock is partially disintegrated, this variety is often called amygdaloid, those foreign matters appearing like almonds, in the rock. Both greenstone and amygdaloid have a granular structure, and feldspar may often be distinguished in small particles, disseminated through the mass. Greenstone is also porphyritic, the crystals of feldspar are distinctly formed during the process of cooling.

§ 79. *Basalt* is a black compact rock, occupying the same relations to other rocks as greenstone, just described. It is both massive and columnar. Structurally it differs from greenstone, in its perfect homogenity. Frequently our trap dykes are perfectly homogeneous and compact, and hence are basalts. Basalt is not a common rock upon the Atlantic slope. The rocks which have frequently been called basalt, are really greenstone, as either by the unassisted eye or by means of a single lens, particles of feldspar are visible.

§ 80. *Porphyry* is a rock in which crystals of feldspar are tolerably well defined. They are embedded in a compact paste. This paste is often reddish or greenish, but the color is variable, or it may be any color.

Fig. 22.

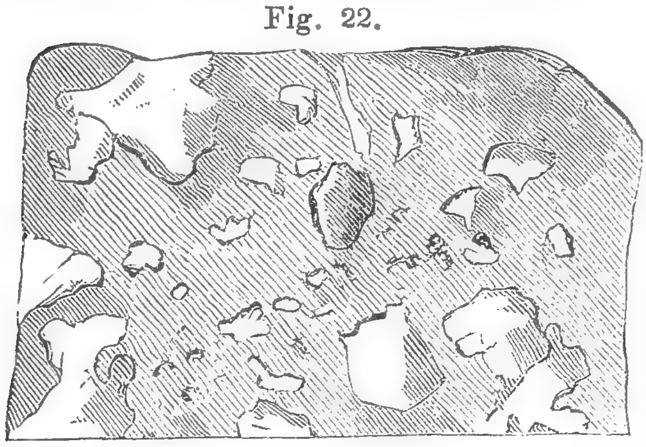
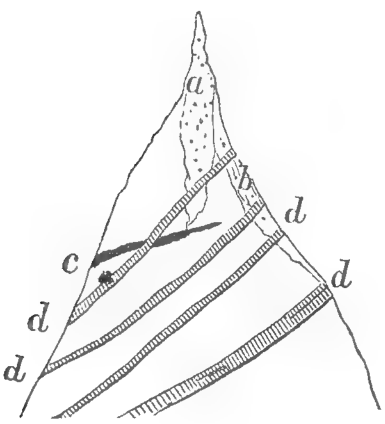


Fig. 22 represents a porphyritic mass, which is common over a large area, in North Carolina particularly, in a belt passing southwesterly through Granville and Chatham counties. The porphyritic structure is rarely perfect. The masses of feldspar in the paste, though tolerably well defined, have rarely straight edges or even planes.

The feldspar is rather concretionary than crystallized. The white spots are frequently quartz.

§ 81. *Trap dykes* are those black stony masses which are interposed between the walls of a fissure. For a limited distance they pursue a straight course. The fissure is perfectly defined, and the filling always perfect. Where more than one dyke intersects a rock, they may be parallel, as represented in fig. 23, or they may intersect each other. In the first case the dykes are probably of the same age, but of a later date than the masses which they intersect. The rock traversed by these dykes is hypersthene, and all the subordinate masses are igneous products.

Fig. 23.



a A mass of Pyrocrystalline Limestone, *b* of Granite, *c* a vein of Magnetic Iron Ore, *d d* four parallel Trap Dykes, which may be traced a hundred yards.

DISTRIBUTION OF THE SUBMARINE PYROPLASTIC ROCKS IN THE UNITED STATES.

§ 82. In the eastern section of this country three belts of greenstone are well known. They belong to the eastern or Atlantic slope of the Appalachians and the Green or Hoosick mountains, and are coextensive with them. Two of these belts are parallel, and were synchronously erupted. The eastern belt begins in Rhode Island, and extends entirely across the eastern part of Massachusetts into New Hampshire. The belt is prominently exhibited in Weston, Watham, Lexington, Woburn, Wrentham, and onwards to Ipswich in New Hampshire. The direction of this belt, upon the whole, bears to the eastward. It is not, however, in a distinct belt or ledge, but a broad area in which these eruptive rocks are common. It is intimately associated with sienite, another eruptive rock which accompanies it through its whole route. The two masses form, as it were, a large patch of rocks, encircling in part Massachusetts

bay.* This mass has disturbed the coal measures of the eastern section of this state, and may perhaps have been erupted at that epoch, as it emerges from beneath them. It may be called the trap of Massachusetts bay. The second belt belongs to the valley of Connecticut river, and passes entirely across the states of Connecticut and Massachusetts. Its direction is north and south, and it has disturbed the trias beds along its line of bearing. It is both massive and columnar. Mount Holyoke and mount Tom are conspicuous eminences in this belt. It may be called the trap belt of Connecticut river. The third belt of trap or greenstone occupies a part of the valley of the Hudson river. It is well known in the southern part of the valley, where it is called the *palisades.* This locality may be regarded as a typical representation of trap. It is both columnar and massive: the former constitutes the prominent feature of the rock. This belt may be called the Hudson river belt. It appears to terminate in a point south of the Highlands, but it is prolonged through New Jersey, and may be traced, with a few interruptions, through Pennsylvania, Virginia, North and South Carolina, and into Georgia. It is associated with the trias of those states, or it may be the permian, inasmuch as there is evidence that the coal of North Carolina is of that age, instead of the age of the oolite or trias, as has been maintained. This range of trap is not continuous the whole distance in the states I have named. It extends through New Jersey in nearly continuous ridges, the eastern parts of which lie between New York city and Newark. It passes into Pennsylvania, and forms ridges in the permian or triasic sandstones, but is more conspicuous in the northeastern counties, arranged on the line of Burke, Montgomery, and Chester counties. The Coneaeaga hills are trap.

In Virginia, upon the same belt of sandstone, the trap ranges between Fredericksburg and Buckingham county, pursuing a southwest direction into Rockingham county, North Carolina.

* See President Hitchcock's Massachusetts Geological Reports.

It continues in the direction to the Yadkin. This branch diverges to the southwest. Another begins near Oxford, Granville county, and accompanies the trias and permian into South Carolina, where it apparently terminates again in Chesterfield district. It has been asserted that the Permian system of sandstones appear in Georgia, about halfway between Savannah and Macon. If so, there can be no doubt of their being accompanied by this belt of trap.

The interesting feature of this formation is the great extent of country it traverses. It is comparatively a narrow belt of rock, and hence it seems to have been ejected through a very long or continuous fissure; and it is not improbable that the fissure extended far beyond the visible belt of trap. The palisades are, for instance, upon this north and south line of fracture, which extends northerly through the valleys of the Hudson, Champlain, and St. Lawrence, in the range of Montreal and Quebec. The trap rarely appears on this line between the Highlands and head of the Champlain valley. At this point trap begins to appear again, and with frequent repetitions down to port Kent. From this place onward to Montreal the disturbance of the rocks is much less, but at the latter place the phenomena justify us in regarding it as the center of a highly disturbed district. It may be traced onward to Quebec.

It does not necessarily follow that this belt was fractured for 400 miles north of the Highlands, in New York, at the time the eruption of trap forming the palisades took place, yet it probably was. This erupted mass ranges along this fractured belt; and if this belt extends to South Carolina, it is one of the longest lines of eruption east of the Rocky mountains. Admitting the fact of the continuity of this long line of fracture, we are led to look for some cause which determined its extent and direction. We have found a part of this belt to be occupied by trap and greenstone, and to form a very striking feature in its geology; but upon other parts of the belt, though the rocks are fractured, and very much disturbed, yet the eruptive rocks do not appear at the surface: for example, between the High-

lands and the head of the valley of Champlain. This part of the belt, together with the more northerly part of it, between Montreal and Quebec, is upon a line of junction between two systems or formations, and the juncture or belt in proximity with it, is made up apparently of the thinnest masses of the systems, and hence is a line of weakness. If this position is true, then, and if it has been one of great tension, it explains the fact of the fracture and disturbance upon the line.

Again, upon lake Superior several distinct parallel belts of trap range in a northeast direction, taking, however, a curvilinear course. These traps consist of compact greenstone, amygdaloid, and basalt; they are also chloritic and ferruginous. The compact variety passes into granular semi-crystalline trap, in which feldspar is visible. The rock is regarded as a product formed by the fusion of labradorite and hornblende. The range extends from the extreme limits of Kewaunee point to Montreal river. Isle Royal is composed of materials similar to Kewaunee point. The geological investigations prove that the trap belongs to the oldest Silurian period, as it alternates with the Potsdam sandstone. Eruptions of trap took place while the sandstone was in the process of formation. This turns, it is true, on the correctness of the determinarion of the age of the magnesian limestone, which rests upon the sandstone. If this is equivalent to the calciferous and chazee limestones of New York, there can be no doubt respecting the age of the underlying sandstone.

It will be observed that the trap is not intruded between the layers of sandstone in the mode represented by fig. 21, where the trap is in wedge-form masses, and which penetrated the rock subsequent to its consolidation. In the lake Superior district, the trap overflowed the sandstone in sheets, which subsequently were covered with another bed of sandstone, and then another eruption covered the preceding with another sheet of molten trap. There were alternations therefore of melted rock and sediments; the two processes were going on at intervals, but during the same epoch.

The ranges of trap in the far west begin to make their appearance just beyond the verge of the crests which divide the waters of the Missouri from those of the Columbia and Colorado. The Rev. Mr. Parker many years since described the basalts and greenstones upon the western slope of the Rocky mountains. These eruptive rocks appear not far from the head waters of the Columbia and Colorado upon the Pacific slope. A large proportion of Oregon, indeed, is basaltic. At the head waters of the Salmon river the gneissoid granite begins to give place to the pyroplastic rocks—greenstone, porphyry, amygdaloid, and basalt—the latter of which walls up the Columbia at many points, as at the Cascades, Willamette falls, Grande Coulé, Walla Walla, the Dalles, Cape Horn, Smoke river, &c. The boundaries of this great region of trap remain, however, undetermined. It is the largest and most interesting geological field of this formation in the United States.

SUBÆRIAL PYROPLASTIC ROCKS.

§ 83. These rocks are erupted from craters, which in their perfect forms are perforated cones formed over a tubular aperture leading to the subterranean incandescent and melted matter beneath. The beginning of a cone is a fissure, simple or stellated, which in giving vent to the melted matter is modified in form and condition. The line of fissure will be filled by erupted matter, while the orifice is rounded by the exit of incandescent lava. The formation of cones has often been observed. Their shape and structure are very uniform. The material is derived from rocks which are melted and partially altered at unknown depths, and being forced upward, escape through the vent, either at the apex or at one side of the cone. A cone will consist in part of consolidated erupted matter collected around the vent. If all the substances formed beneath consisted of fused or liquid rock, flowing out at one side, the symmetrical cone would not be formed at all: but as ashes and cinders are ejected, they fall around it, and in the course of a few hours a

cone is built up about the orifice of the loosely coherent materials.

Volcanic action is not accompanied with the same phenomena at different times; neither do the different volcanoes eject the same kind of material at different epochs of eruption. At one time it is a thick heavy lava, which pours over one or two sides of the crater, and slowly flows down the mountain. The volcanoes of the Sandwich islands are boiling pools of melted rock—excavations rather than craters, and their activity is accompanied with moderately loud explosions, and the shrill hissing of steam issuing from a boiler. Sometimes, again, the volcanic products consist of ashes, which fall in part around the crater, while the finer particles are driven to distant countries by the winds. While the ordinary products of volcanic action consist of melted rock sufficiently liquid to flow, or of comminuted rock in the condition of an ash, there are still many other products which escape at certain times from different volcanoes. Thus gases and vapors are common. Among them are nitrogen, ammonia, carbonic acid, carbureted hydrogen, and sulphureted hydrogen; boracic acid also escapes in the steam in company with ammonia. Hot water, holding silica in solution by means of potash or an alkali, is a common product of volcanic action in Iceland. Bitumen and naptha also are found among those products, especially at Taman, at the western extremity of the Caucasus, and at Baku, a port on the Caspian sea. The latter are mud volcanoes or salses, the bitumen and naptha being derived from the superficial deposits of organic matter. The strongest indication of volcanic action in our own country was exhibited at New Madrid in 1811. The hot springs of Wachita, and those of California, witnessed by Mr. Forrest Shepard, must be regarded as due to a feeble volcanic action.

A phenomenon which stands connected directly or indirectly with volcanic forces, is the earthquake. It immediately precedes, and perhaps continues during the first outbursts of this force. The earthquake consists essentially of movements of the

earth's surface in the form of waves or undulations, which travel with great rapidity in all directions from the focus of disturbance. The intensity of this movement, or the force of the shock communicated to the strata, is supposed to be in some way dependent upon the diameter of the vent through which gases and melted matter have escaped. The openings of Vesuvius, Etna, and the South American volcanoes, are narrow and constricted, and at the same time their coverings over and above the seat of activity are thick, and strengthened by repeated accessions of layers of rock from beneath, and braced by numerous intersecting dykes. Under these circumstances volcanic forces are confined by strong walls and narrow funnels; and hence, when the forces have acquired strength sufficient to rend asunder these walls, or force the safety-valve, it will be attended with tremendous earthquake shocks. On the other hand, where there is an opportunity for a free escape of gas and melted matter, as in the Sandwich islands, Mouna Loa for example, where the craters are rather deep and wide excavations, volcanic action of great intensity begins without endangering the surrounding country by earthquakes. The seat of activity seems to be more superficial, and the resistance to be overcome far less, than those of South America and Europe. An eruption of the volcanoes of Europe and South America, therefore, is attended with violent movements or undulations of the crust, which are propagated from the center of action in all directions. It is to be recollected, that as the crust is not homogeneous, and the material through which the impulse is propagated is not equally dense, the effects of that impulse must be modified in its transit. The impulse here spoken of generates a wave in the crust which usually moves onward, as has been already stated, with great velocity in all directions from the center which receives the first shock of the explosion. The surface rises and falls like waves of the sea; or, in other words, the undulations travel onward with great speed in obedience to the ordinary law of a force propagated through a resisting medium. The undulation is modified, how-

ever, by the position and condition of the resisting medium. In its progress, a direct undulation may be converted into a gyratory one by an increased resistance in its course, or into a vertical one at the place situated immediately above the point of impulse. An instance of direct earthquake undulation, extending over a large portion of Europe, a part of Africa, the Atlantic ocean, and West India islands, is well known in the remarkable visitation of Lisbon in 1755; of the gyratory, or of the vertical movement, which took place in the great Calabrian earthquake in 1783, by which two obelisks at the convent of St. Bruno were twisted on a vertical axis without falling. Of the vertical movement, a striking example occurred during the earthquake at Riobamba, 1799, where a sudden rise of the ground took place, which hurled the bodies of men to a height of several hundred feet.

Considering earthquakes as earth-waves, it is evident that when those waves are generated in the ground beneath the ocean, their impulse must be communicated to the water above, whose motion will partake of the same character. Waves will therefore be generated therein, which will travel onward in directions which the impulse communicates; but from the nature of the medium, the water-wave will travel with less speed than the earth-wave. In consequence of this fact, a person upon a shore where the two waves are tending, will experience first the earth-wave, and soon after the water-wave will follow; lastly, another wave will be recognized through the medium of the air. In each of these cases the rate of transit depends on the nature of the medium receiving the shock. Experience proves that the intensity of the shock is very variable in volcanic districts. It does not, however, seem to depend directly on the activity of volcanic action, for according to Dana, the activity of Kileaua is not exceeded by that of any other volcano; yet earthquakes are rare and feeble, even when a force immeasurable by us in its power is manifested in some of the results of this action, especially in rending the earth for twenty-five miles without having produced an earth-wave

worthy of notice; while in other cases the visible activity is much less, but is accompanied with disastrous and terrific effects.

A fact should be stated in this place, which is probably the most important one which attends volcanic activity—it is the change of level which a country often suffers during its paroxismal throes. The coast of Chili, for example, in 1822, was permanently elevated for one hundred miles, in some places more than ten feet, in others less. Large areas in all countries furnish many facts in proof that they have undergone a similar change of level. It is not determinable now whether those changes occurred during a single paroxysmal effort; but where a coast has been stationary a long time, and then appears to have been stationary again at a higher level, the probability favors the paroxysmal view. But wide areas are elevated slowly, and apparently uniformly. Where the change is going on slowly, as in Scandinavia, and perhaps on our own coast, it may be due to the expansion of rocks by heat.

CAUSES OF VOLCANIC ACTION.

§ 84. Much has been said and written of the cause or causes of volcanic action, and for the solution of the question many ingenious and indeed philosophical reasons have been proposed. Among the causes assigned, chemical action, excited by electro-magnetic arrangements, has had many advocates. Known analogies are favorable to this theory. We may arrange our apparatus, or we may devise in the laboratory the needful conditions for imitating nature's processes within the earth, hence its favorable reception; and it is not strange that chemical forces have been regarded as the prime agencies of volcanic action. When we take, however, a larger view of the facts and phenomena which constitute in the aggregate the volcanic forces, we can hardly refuse to admit that the chemical actions which no doubt go on on a magnificent scale during the eruptive periods, are effects and not causes. We are therefore driven to the necessity of going still farther back in order to

find the primal cause; and it is no disparagement to the intellectual power of man to acknowledge, that respecting the primal cause we see only the hand of infinity who kindled the once blazing fires of the universe of matter. How or when, are questions too deep for us to answer. We may therefore regard the primal cause as the remains of that original incandescent state, and it is the prolonged activity only of the burning mass which has but just retired to the deeper parts, above and around which the crust has become scaled as it were by simple cooling.

As terrestrial volcanic action is to us the most interesting of geological phenomena, this circumstance alone has led both geologists and astronomers to scrutinize with great care the only heavenly body which admits of examination, in order to ascertain if our satellite shows indications of the same agencies of which I am speaking. The result of these examinations has clearly proved that the moon has been the theater of intense volcanic action. This luminary, which shines with such silvery light, and appears so plane and even, becomes under the telescope studded with rough and rugged mountains, whose tops are crateriform, or its planes have the semblance of deep excavations, in which are standing sharp conical peaks, perforated like the cones of Vesuvius, Etna, and Cotopaxi.

Our satellite, then, is but a smaller pattern of the earth, exhibiting, an intenser volcanic action than that of the earth—a fact which is probably due to the absence of water, an agent which upon the earth has modified its surface so far as to conceal in part beneath the sedimentary rocks its original volcanic nature. The moon, however, presents its face covered with ancient eschars, which time never has healed, and which are destined to remain in all their original roughness and rigidity.

In illustration of lunar volcanic phenomena, I have presented the student with a crystallotype of her surface, which was taken by Mr. Whipple with the Harvard telescope. It will be observed that her surface is studded with prominences which

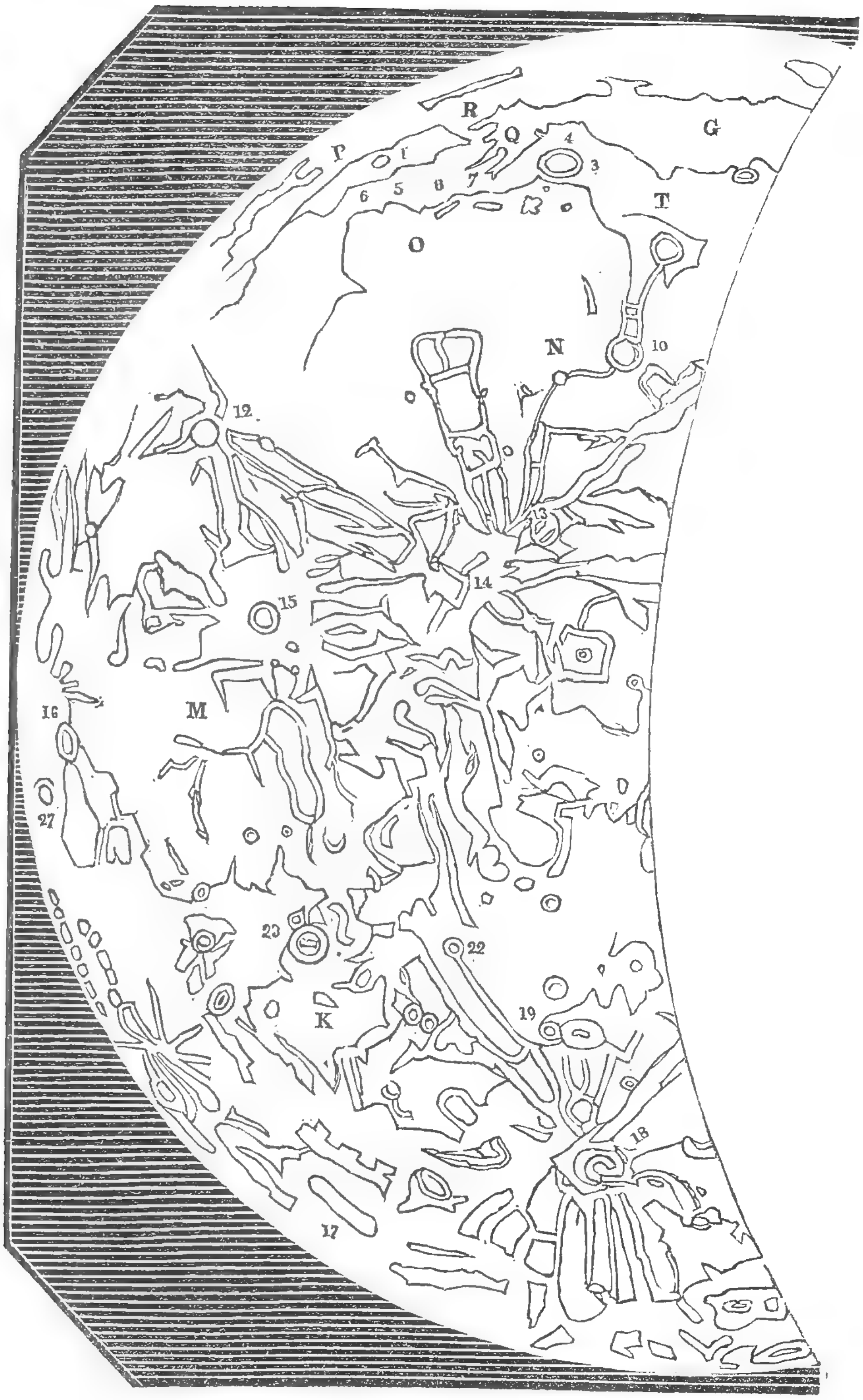
represent faithfully its structure. The strong shadows, which are visible under the telescope, are but faintly perceptible in this likeness. But what is particularly worthy of notice, are the lunar craters, which are represented by the circular projections upon different points of her face. The stellated fractures or fissures produced by soulevements of her crust, are among the remarkable features of the portrait.

In order that the student may locate the lunar volcanic peaks, I have copied a diagram from the Penny Cyclopedia, fig. 24, upon which the relations of many of their points may be observed at leisure. But I would particularly recommend the study of the moon's surface by means of a good telescope.

The arrangement of lunar volcanoes, like those of the earth, is very nearly in lines, which indicates their connection by means of passages beneath. Considering the mass of the moon, and the rapidity with which heat escapes into space, it is probable volcanic action has long since ceased, and that its primal fires were long ago extinguished.

The moon has neither an atmosphere or water upon her surface. The temperature of the moon is different from that of the earth. She has fourteen and three-fourths days of sunlight, and of course the same number of days (terrestrial) of darkness. Intense heat and cold succeed each other. The moon's mass is $\frac{1}{80}$ of that of the earth, and the average density of her material 0·615 or $\frac{6}{10}$ of the earth. Hence a body weighing six pounds at the earth, would weigh one pound at the moon, if each weight retained its terrestrial gravity. Some of her circular or cusp-shaped mountains exceed one and a half miles in height. I have already spoken of their volcanic character.

Fig. 24.



An Outline Plan of a part of the Moon's Surface.

The following are references to the most important points upon the moon's surface: 1 Pythagoras, 3 Plato, 4 Aristotle, 5 Hercules, 6 Atlas, 10 Archimedes, 14 Copernicus, 15 Kepler, 18 Tycho, 23 Gassendus, 19 Pitatus, 16 Helvetius; G Mare frigoris, M Oceanus procellarum, K Mare humorum, T Terra grandinus.

SECTION OF THE EARTH'S CRUST.

§ 85. This section is designed to illustrate the structure of the earth's crust at the parallel of 40° or 45° N. If a segment of the earth were cut off at this parallel, we may suppose the lower part of the consolidated face to consist of pyrocrystalline rocks intersected by veins of the same material, but of a date posterior to the original consolidated matter. These veins consist of the newer granites, dykes of trap, serpentine, veins of iron, copper, lead, &c.; and as there is no country which has been explored, which does not furnish clusters of veins and dykes of some kind, we may regard the crust as constituted of pyrocrystalline rocks, penetrated everywhere, and traversed by a network of veins. As Vesuvius, Etna, and South American volcanoes are but ejected matter in beds, which are fissured and dyked in every direction, so the general crust may be regarded as equally fissured and traversed by the more recent of the erupted rocks in the form of veins and dykes. It has been stated in the preliminary remarks, that the bottom of the ocean is not a plane, but an irregular surface of the same character as the dry land—sinking in places to the most profound depths, and rising again in mountain peaks, some of which reach the ocean's level, while others peer just above it. All those parts of the earth's crust which lie beneath the area, represented as America, Europe, and Asia, were once beneath the oceans. The vast amount of sediments which are accumulated upon these continents show the vastness of the time during which they were covered with water; and as the extreme height of the mountains of these continents nearly equal the profoundest depths of the oceans, the vertical exposure of the crust, or the depths to which our observations may extend, rather exceed 60,000 feet.

The only points to which I wish to call the attention of the student, on the physical map of the world, are the general directions of the old and new continents, both of which were determined by the direction of the upheaval of their principal moun-

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tain chains. In the old world the direction is nearly east and west, and in the new, north and south; both continents are therefore prolonged in the direction of these mountain chains. The description of the subordinate mountain chains will be furnished in a subsequent part of this work. The geological column is designed to show the relation of the systems of rocks to each other. The sediments or hydroplastic rocks are represented as reposing upon each, according to their age; and though the pyrocrystalline are represented as lying also one above the other, this is by no means the constant order of arrangement. Fig. 1 represents granites of different ages, penetrated by a volcanic funnel or tube, terminating in a crater. Figs. 3 and 4 a trap dyke and vein intersecting the laminated pyrocrystalline rocks, which consist of masses of gneiss, mica slate, hornblende, and talcose slate, upon which the oldest of the sediments, the Taconic system, reposes. At different places, however, the several systems of sediments are found reposing directly upon the primary and crystalline rocks. Thus the permian system in North Carolina; the new red of the Connecticut valley rest upon the pyrocrystalline rocks, proving that the places where those rocks are spread out and deposited, were subærial until these geological periods. The relative lengths of the geological periods are approximately represented in the column. It shows to the eye that the paleozoic periods were immensely longer than the messozoic and kainozoic. These periods are the great triads of geologic history. The paleozoic, is the period remarkable for its duration; the other, for the rank of the organisms entombed in their strata.

APPLICATION OF GEOLOGICAL FACTS AND PRINCIPLES TO THE BUSINESS OF MINING.

§ 86. Mining can be conducted safely only by employing the principles of geology as guides in conducting its labor. It is, therefore, a practical application of the observations of geologists which constitutes scientific mining. Mining, as commonly understood, is the extraction of ores from the beds and veins which they occupy in the earth. Its signification, however, may be extended so as to embrace the removal of rock as well as ores from their beds; embracing, also, what is usually known as quarrying.

Though mining is strictly the application of labor, as I have just defined, yet it has its theoretical part which is really of great importance, especially when facts form the foundation of those views. These constitute the philosophical part of the business. The skillful laborer will not disregard this part of the subject; it will even aid his mechanical labors in detaching the useful parts of the mine or of a quarry from their beds, and assist him in bringing to light the riches hid in the earth's bosom.

Mining, in the comprehensive sense in which I design to use the term, may be treated of under the following heads:

1. The theory of the formation of those depositories which contain the metals and ores.

2. The structure of those depositories.

3. The changes which the mineral undergoes in depth.

4. The best modes for extracting their metals and ores, including those which have been devised for raising blocks of rock from their beds.

5. The expense attendant upon different kinds of work in mining and quarrying.

6. The value of the products of mining.

1. In the foregoing part of this treatise I have already had occasion to speak of points which belong to, and which also

illustrate, the subject under consideration. Notwithstanding this, it will be necessary to recapitulate certain facts and principles which have an intimate bearing upon the subject.

In the first place, we must look upon all the repositories of the ores and metals as ancient arrangements, by which they are made accessible to us; and that those arrangements are the necessary result of the constitution of the globe. They are by no means to be regarded as accidents, arising from conditions which might have been otherwise. They, too, are general results, confined to no limited scale; and when the forces and plan were determined, upon which to form and fashion the earth, the results of which I have spoken became an essential part of those causes, and it would have required special instrumentalities to have prevented their operation just as we now see them to have operated. It is for this reason that the formation of repositories for the metals has been controlled by law, by which certain constants may always be looked for. This being the case, the miner has not overlooked the plainest of these results, but is constantly referring to them in his operations with confidence.

It is not necessary that we should connect these laws with the early conditions of the globe, in order to understand them; but as facts it is proper that they should be borne in mind. What was that original condition, then, which gave birth to the repositories of the metals? It was that incandescent state of the crust of the globe, of which I have already had occasion to speak. We have no occasion now to inquire what gave birth to that incandescent state; the fact is attested in the phenomena everywhere visible in those portions of the earth's crust which belong to its earliest epoch. The most important effect of this state is the expansion of the crust, or the occupation of a larger space for the time being. But the earth, situated in space, and in a colder medium than itself, has necessarily lost that primitive heat which belonged to its earliest stage of existence. It has cooled, and the most important result which interests mining, is the consequent contraction of the cooled

part. Contraction has severed the bonds of the continuity of the strata; and those fractures which are the result of the cooling process have been made in comparatively straight lines, or in given directions; or we may regard the causes of fractures simply as subterranean, but due to general conditions, and which must necessarily affect the whole of the cooling envelope.

The fact that fissures may be, and probably are thus formed, is agreeable to all that is known of cooling bodies; and observation which has been directed to those fissures proves, in the general at least, that the fissures are made in lines of bearing quite constant. We may not infer that a mechanical force is applied beneath a stratum, and has erupted those strata in the lines I have spoken, as a previous step in the formation of a vein. A cooling state has given rise to a state of tension, which increases in the direct ratio of the diminution of temperature, which is finally too great to be borne, when the continuity is broken. It is true that a subterranean force is often operative in the mode represented, and by which strata are uplifted and fractured; but it is more consonant to facts to suppose that vein fissures are the result of cooling and the great tension which arises therefrom. As a general rule the direction which a fissure has taken was in a line of the weakest part of the stratum; but it is easy to conceive that a greater strain may be made upon a stronger part, so as to form a fracture in a line which is apparently along the strongest part of the stratum. In crystalline rocks the planes of lamination must be regarded as weaker planes, and hence it is that a very large proportion of our veins of magnetic iron lie along those planes.

Having alluded very briefly to the force which has been operative in the formation of vein fissures, it is proper that I should speak of the manner and force by which they are filled. It is in the first place admitted that the matter which fills those fissures was liquid or semi-fluid at the time it passed into them; and furthermore, that the vent produced by over tension extended to the liquid or semi-fluid mass below. It is inconsistent with known facts to suppose the fissures to have been filled

with matter in a solid state. The filling of fissures, then, is supposed by many to have been effected by subterranean forces analogous to the forcing of fluids upwards, or in any direction, by the elastic force of vapors acting upon a molten mass; or a new way being opened, it is forced by the elasticity of vapor into that way. It would be difficult to disprove such a view of the manner, but under certain conditions it is unnecessary to bring to our aid the elastic force of any fluid; for a fissure being opened so as to communicate with a semi-fluid matter below, would necessarily fill instantly, in consequence of the vacuity of the fissure itself. It would take place in the same way that water rises in an exhausted receiver of an air pump; or it would rise up and fill the vacuity by what is sometimes called suction. This view comports with the remark, that means would have to be devised to prevent the filling of fissures under the present arrangement. Again, it is evident that veins are not always opened to the width we find them by one single operation of the force of tension. In the regular cooling of the crust, which goes on subsequent to the formation and filling of a fissure, it is evident that as the cooling may still go on, the tension or strain will begin anew. Now, under these circumstances less force will be required to widen anew the former fissure; for we can scarcely suppose that the filled fissure will unite the torn edges of rock so as to equal at all its former strength of attachment: the fissure will therefore run along the line of the old one with ease and certainty, because that has now become the weak part. This will result in the addition of new matter to the vein; and it is not at all improbable that in the extent upheaved, as well as in the line of bearing, it may be increased.

I am disposed to adopt the foregoing view of the manner, as well as that which relates to the force by which fissures are filled. I do not reject, however, the view which brings in the instrumentality of an elastic force of a gaseons fluid, by which the semi-fluid matter is forced upward into a fissure. Both

modes have undoubtedly been operative under different circumstances.

But, again, there are other kinds of veins—those which have no communication above or below with a fluid or liquid matter. They are fissures which begin, and which end in the rock, and yet these fissures are filled. In furnishing an explanation of cases of this kind, we must recognize the existence of the same forces as those which I have alluded to. The fissures are produced by tension in a cooling or drying mass, and when they terminate in the rock the fissures are absolute vacuities—each fissure is a vacuum. The filling of such fissures is effected in a mode similar to that already intimated—by fluids charged with lime, or any matters contained in the rock which are soluble under the circumstances; for towards the fissure soluble matter will tend, and crystallization will take place, and the fissure will ultimately be filled with it. It may be inquired, how it happens that veins possess such a uniformity of width. It may be answered satisfactorily in this way: a given rock, mica slate or gneiss, possesses a great degree of uniformity in texture, and hence the different parts of the mass expand or contract alike by equal increments of heat. A fissure may proceed from above downwards, as the outer surface will cool faster than the inner; but its subsequent extension through this uniform mass of matter will form a fissure of nearly the same width throughout, though it may be successively formed. We may justly suppose, however, that in case a fissure proceeds from the outer surface inwards, the resistance of tension will be less in the interior and lower parts of the rock; hence a fissure may rend the lower stratum, as it were prematurely to a great depth, the tenacity being proportioned to the state of consolidation.

We can with difficulty resist the conclusion, that as fissures are formed by the cooling of the surface, the width of a fissure must necessarily be wider at the surface than at considerable depths in the interior. The true mode of representing fissures or veins in diagrams should be in accordance with this view.

The depth, however, to which mines penetrate the earth's crust is exceedingly small compared with the earth's semi-diameter, or even with that of fifty or one hundred miles. We have no occasion, therefore, to attempt to illustrate this principle by a different mode than the one which is usually employed.

But another fact may require a word of explanation. A fissure or vein is shifted, or is jogged out of its line of bearing. We may suppose in such a case, that while cooling, the stratum is subjected to an unequal tension of its parts, or to a tension in two directions. Hence, we may infer that a shift in the position of a part on one side of the fissure may take place at the moment the tenacity of the rock yields to this force in another direction. Or the shift may take place at a period long subsequent to the first fissuration, by the tension in an opposite direction to the first; the shift taking place by an unequal support of the mass. I can not conceive that the force of the entrance of the matter of the vein, tends to the displacement of the stratum. Its entrance acts equally upon the sides of the fissures; and though it is evident that there is considerable friction upon the sides by the striation of the walls and the vein-stone, still, it may be due to the weight of the mass resting upon an unstable foundation.

If a fissure opens to the surface from a great depth, but does not extend to the molten mass beneath, it becomes a water course, a *drainage* fissure, upon the sides of which incrusting matter will be deposited. This is called veinstone, or the gangue, and with its metallic associates forms the vein. The upper part of a vein fills, or is filled, in part, by veinstone intermixed with metal in specks or small lumps, which are diffused through it very sparingly at or near the top, but with an increase of depth increases in quantity.

In addition to the function of drainage, fissures may become *galleries of sublimation*, in which the sulphurets, chlorides, &c., will be deposited. Metallic zones and stripes of metal will traverse the gangues wherever they are penetrable by subterranean exhalation. The exhalations passing upwards through the crater

of a volcano, carry up with them ferruginous combinations, which condense on spicula of lava, or colder pieces of rock, which project into the passage. The sulphuret of lead melts in the furnace, and in cooling returns again to its original sulphureted state. Both lead and copper volatilize by furnace heat, and may be condensed again; so subterranean exhalation will condense upon the cold surfaces of fissures. These facts leave, however, other facts observed in mines unexplained. The Rossie mines furnish large, fine crystals of sulphurets as well as crystalline masses enclosed in crystals of calc spar; a fact which seems to sustain the view that the materials were mingled together in the great furnace beneath, and were ejected bodily into the vein. In all those cases where lime and the sulphurets are intermingled in this way, it is evident that their fusion took place under great pressure, otherwise they would both have been decomposed, and it is highly probable sulphates would have been formed; as it is, we have reason to conclude that the minerals fused without parting with their sulphur or carbonic acid.

From the foregoing views, we are justified in the belief that vein fissures are not filled by one mode only, but that they may have been filled by two or more modes conjointly; the upper portion by endosmosis in part as a drainage fissure, and the lower by injection, or by pressure, or sublimation. The copper veins of Cornwall rarely contain copper at less than a hundred feet from the surface; yet there is a fissure with its veinstone. I have said nothing of the electro-magnetic force as an agent, for I conceive that the detection of this agent is not proof that it has been operative in the modes assigned to it.

I have probably presented the simplest view of the formation of metallic veins; and if no other agencies were operative than that of the cooling of the earth's crust, the business of mining would be less complicated and more certain than it is. It is to be recollected, however, that consolidated rocks have been subjected to many disturbing agencies at different times, and it is well known that a mining district is always one in which those agents have been particularly active. An undisturbed district

is never a mining one, though it does not follow that all disturbed districts are rich in mines. But without doubt all mining districts have been the seat of great disturbances of the strata. They have been subjected to chemical as well as mechanical forces; strata have been crushed and displaced by faults, and along with those displaced strata their mineral veins have suffered displacement also.

CONTINUITY AND PERSISTENCE OF VEINS IN DEPTH.

§ 87. The expenditure of capital in mining, is warranted only where there is a good degree of assurance of the persistence of the vein in a downward direction. While it must be admitted that each particular case should have its own evidence of its continuity, still that evidence is based on general facts and principles. We refer in the first place to the theoretical views we have offered relative to the origin and formation of veins. If that theory is sustained by observation, we are carried a great way towards a satisfactory establishment of a persistence of veins in a downward direction; subject, however, to an interruption, it may be by the operation of local causes, which may have deranged or interrupted the formation of the vein fissure. We may not, however, neglect the teaching of facts as they are being furnished by the workings of the oldest mines. To the mining records of other countries where it has been the business for centuries, we may refer with great satisfaction. The veins in the mining district of Cornwall, England, have been pursued successfully to the depth of 1800 feet. It was thought by one class of geologists that they had become less rich at the depth of 600 to 1200 feet; still they appear to retain their richness to day with very little or no abatement, to the depth of nearly 2000 feet. There are still deeper mines in the districts of the Hartz mountains. Those of Clausthal and Zellerthal have been pursued to the depth of 1920 feet. Those in the district of Andreasberg, 2400 feet. In the neighborhood of Freyberg, Saxony, the mines have been worked to the depth of 1800 feet. The Mexican silver mines, have been explored to

the depth of 1500 or 1600 feet; and the quicksilver mines of Almaden, in Spain, have sustained their richness beyond the depth of 900 feet.

The continuity of veins in the direction of their strike, has not been determined with exactitude. Some of the veins of Freyberg are known to extend, in length, from 12,000 to 24,000 feet. Another is known to extend 36,000. But in the direction of their strike or bearing, there is a great variation in their condition. An auriferous vein of quartz in Maryland, extended only 20 or 24 feet in its line of bearing, plunging down at each extremity on a rapid slope; and yet there is little doubt that its depth continuously is as great as any of the auriferous veins of our country, whose line of bearing may be traced for one or two miles. The records of mining furnish many curious, as well as interesting facts. Veins are often explored for several years without returning a compensation for the labor and expense incurred, when they are abandoned. After many years of rest, an enterprising miner or capitalist, who is acquainted with the history of its former working, having faith in its value, reopens the mine and pursues it with great success. Occurrences of this kind are common in all mining countries. They show in the first place what superior skill may accomplish; or, indeed, the subsequent success may have arisen not so much from superior skill in working, as from having opened a richer part of the mine. All experience in mining proves that the wealth of a mine is variable; some zones are rich, while others are comparatively poor; and this fact is one which should be universally known; it is one which the capitalist should be prepared to meet in any mine, however rich it may be at certain points of exploration. This remark is applicable to veins of lead, copper, silver and gold, rather than of iron.

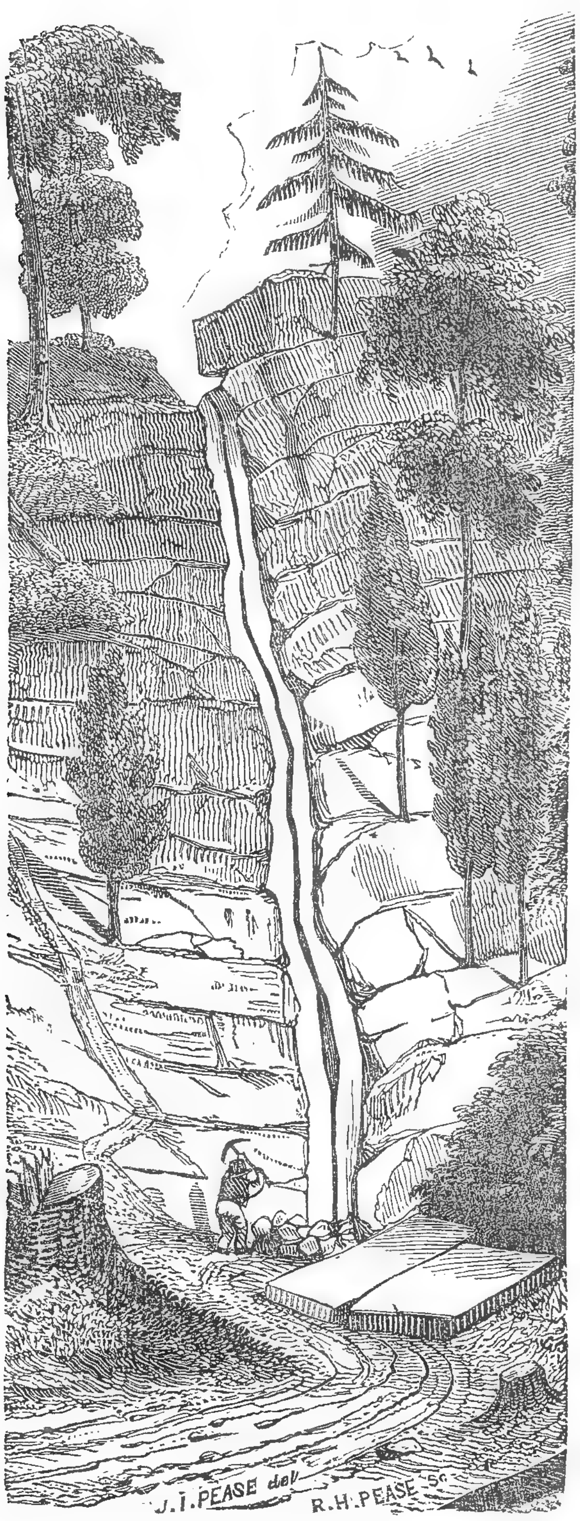
Veins have been observed to terminate in the direction of their strike, in many thin branches, which appear to be lost in the rock. It is not, however, determined that those smaller branches are always the extreme ends of those veins, for the fissure may have opened wider beyond their apparent termina-

tions, and hence be prolonged still farther. Vein fissures extend beneath the soil farther than the indications upon the surface warrant us to expect. In the direction of the strike they may plunge down beneath the surface on a gentle or steep slope. The outcrop is lost—the fissure does not extend to the surface—the lamina of rock are in contact—and yet the vein is prolonged, and may reappear in an outcrop, several miles from the points where it is known. The argentiferous galena vein of Davidson county was struck in an excavation six miles northeast of its principal workings, and yet the surface gave no signs of its presence beneath. In instances of this kind, the vein plunges downward to an unknown depth, when it takes an upward movement and ascends to the surface. The fissure may be filled, however, with veinstone only, and hence excites no attention. The foregoing statement proves the existence of vein fissures which do not reach the surface. The same fact has been observed in dykes; they penetrate the inferior layers of a rock, but the fissure not extending to the surface, and the stony matter having no power of itself to form a passage, stops at the upper limit of the rent. Branches of veins, too, are often cut in sinking shafts at many levels, which have no connection with the surface. These facts illustrate the direction and mode in which those vein fissures have been filled, and clearly point to their igneous origin.

As the quantity of metal which a vein carries is variable at different points on its line of bearing, so it is also variable at different depths. It may be variable in consequence of the diminished amount in the vein, which at the bottom preserves its ordinary width, or it may be diminished by a contraction of the whole vein in width. It may be pinched out, and the veinstone, together with the metal, becomes a mere trace or string, retaining its position between the walls. The variation of the latter kind is well illustrated by the terminal outcrop of the Rossie lead mine, which is exposed in an uplift of the mass of gneiss in which the vien is enclosed, as is shown in the annexed cut, Fig. 25. It will be observed that while the vein is exposed

for about forty feet, it may have an average width of eighteen inches, it bulges out and contracts at many points upon the line of exposure, and is four feet thick at one of the places of dip. It will be observed, also, that the vein is not perpendicular, the rent is not even or vertical, but one which is inclined; or in other words, it has a dip slightly variable at different points, but which, when followed down for one hundred or two hundred feet, or more, is found to be constant, so as to conform to those of the district. The direction of dip may be depended upon, and shafts are often sunk two or three or even four hundred feet, with the expectation of cutting it at one of those depths. Sometimes a vein which dips eastward at the surface, is found to dip westward at 80 or 100 feet. The indication that such a change may be expected consists in the character of the disturbances at the surface. The dip at the surface in those cases is entirely at variance with the common dips of the veins of the district, and the existence of dykes and faults, show that something unusual has taken place. The veins of a district usually dip in the same direction; and when a vein dips in a contrary one, under the circumstances I have stated, there is ground for expecting that at a certain depth this vein will change its direction.

Fig. 25.



STRUCTURE OF MINERAL VEINS, TOGETHER WITH THE KINDS OF VEINSTONE WHICH CONTAIN THE ORES OR METALS.

§ 88. A metallic vein is originally a fissure of an unknown depth and length, bounded by two walls of rocks, whose composition differs from the contents of the vein fissures, and from which the latter easily cleaves. When the fissure or vein is not vertical, the wall against which the vein rests is called the foot wall, and the other the hanging wall. These walls are sometimes called the floor and roof of the vein.

The structure of a vein is simple, and we have no occasion to multiply varieties. A dyke is the simplest and least complicated of that class of veins. It is a fissure filled with stony matter, with specks of sulphuret of iron disseminated in small quantities through its substance. It seems to have been formed and filled at one time. A mineral vein consists of stony matter and the oxide and sulphurets of the metals, and sometimes with pure metals; as the native copper and silver of lake Superior, and the native gold and copper of North Carolina. It is necessary to learn the character of the veinstone, before an opinion can be formed of the probable value of the vein. If the veinstone is solid and compact, the judgment will be unfavorable to its productiveness. If it breaks easily, or if it is porous and seamy, the judgment will be favorable for its productiveness. In a solid veinstone or gangue containing disseminated metal in isolated particles, and which do not run together as it were, the encouragement for a valuable vein is small, as long as it continues in this condition; and a vein of this description rarely assumes a favorable character. If, however, the veinstone is striped vertically with metal, or if the masses are elongated and run together, the prospect is favorable; the metal is assuming a vein-like character. The metal may possess only the disseminated character at the top of the vein, and may pass into the veiny character below. The beginning

of this change is always regarded as a favorable indication, and an encouragement at least to pursue it to a greater depth. A vein is often laminated. The metal and rock being arranged in parallel stripes, it possesses the parallel structure of gneiss. This structure is regarded as one of the most favorable changes,—one which will ultimately lead to the formation of a productive vein. The lamination of a vein is unlike the lamination of gneiss and mica slate; it is always vertical. The structure is sometimes developed so prominently that a question arises respecting the periods of its formation. The indications suggest the probability that the vein was filled by successive openings. At each opening it received an accession of new matter from beneath. I have already stated that the first fissuration may not have communicated with the metalliferous matter, and hence is merely a *drainage fissure*, a receptacle of stony matter. For example, we often find that an auriferous vein is composed of two parts; one of copper, which lies next to the hanging wall, and which is most stony, and a lower mass, which lies against the foot wall, and which is metalliferous. In an example of this kind the fissure may have been widened by the same force which produced it in the first instance. It is upon the foot wall that we look for the greatest quantity of metal. But the metal may pass from the foot to near the hanging wall; and it is frequently central, as in the Rossie lead mine. From the foregoing remarks it will not escape the notice of the reader, that a vein consists mostly of stony matter or gangue, the metal being distributed through it in elongated branches, which run together; and there may be two or more such confluent ranges of metal arranged in parallel stripes, and which are separated from each other by an excess of stony matter.

The foregoing statements may be taken as a general description of the structure of all productive veins, without regard to the kind of mineral which forms the gangue.

INDICATIONS OF A GOOD OR BAD VEIN, JUDGED OF BY THE CHARACTER OF ITS WALLS.

§ 89. The structure of a vein furnishes important information respecting its value, as I have already intimated. The walls, however, are not to be passed by unheeded. In the first place, we look for clear and well defined boundaries between the vein and wall; and if the walls are marked with what the miners term slickensides, which are polished striations more or less vertical in direction, the indications of a well-formed vein are sufficiently satisfactory. Sometimes, however, the walls are not equally well defined. We look in this case to the foot wall, and miners are generally satisfied if they find this hard or firm, and distinct from the veinstone, even if it is not marked with slickensides.

As regards the indications of a well-formed vein in its structure and character of its walls, we find that a porous veinstone furnishes the best indications, especially if the gangue, with the metal, is arranged in parallel stripes, the bunches elongated and confluent, or become more so as the shaft increases in depth. On the contrary, where the ore or metal is sparsely disseminated in a hard, compact, tough gangue, with scarcely any tendency to become confluent, in a veinstone of this description, the indications of a well-formed and productive vein are unfavorable. So also where the vein, though tolerably distinct in parts, is mostly incorporated with the walls, or what are taken for walls, the indications are unfavorable. I have said nothing of the judgment we should form of the increase of metal as the shaft increases in depth, for it is sufficiently plain, that in this country, there should be an increase of metal within forty feet of the surface. The kinds of veinstone are numerous; and how much the value of a mine is dependent upon them, is not well determined, excepting the general fact that some are much softer and more workable than others, and require less expense in working them.

The veinstone in which gold, silver, lead, copper and zinc are found, in this country, is generally quartz, or in the language of miners, flint; and we have numerous examples of rich and poor veins in this kind of gangue. I know of but one lead vein in North Carolina which has a calcareous gangue. The following kinds of mineral form the veinstone of sundry mines in this country: Quartz, calcspar, pyroxene, hornblende, feldspar, phosphate of lime intermixed with a small quantity of hornblende, prhenite, and magnesian carbonate of lime. Either of these minerals may form good stoping ground, or either of them excepting the calcareous may be bad or hard. Much depends upon the connection of the gangue with the wall; if this is such that a gad or pick can be employed in taking down the vein, it belongs to the kind called easy or good ground. Quartz sometimes partakes of the mineral character of a hornstone; it is then an exceeding tough rock; it is an expensive vein to take down, and though it may be rich, yet the expense attending its working is so great as to consume the expected profits.

CHANGES WHICH A VEIN UNDERGOES NEAR THE SURFACE.

§ 90. Every miner has observed that the part of a vein near the surface, differs from that below. The change takes place at that depth where water always remains. The difference between the part of a vein near the surface and that below water, consists in two particulars. There is first a mechanical difference in these two parts of the vein. The veinstone is porous, and the metals are oxides, in loose, slightly coherent masses. I have in mind the gold veins of the south. In the second place, below water, the veinstone is more solid, and the metals are sulphurets, disseminated in the gangue. The upper part is brown, or reddish brown, and the quartz is thus stained; while below, the gangue is blended with specs of metal, or perhaps with the elongated masses. This change in the character of a vein is due to the action of the atmosphere, aided by the alternations of dry and wet states to

which the vein is exposed. In consequence of the changes of which I am speaking, many intelligent miners believe the vein has become poor; and in this opinion he is sustained by the fact that as usually worked, the profits have very materially diminished. But this result is due to what nature has done for the upper part of the vein, by detaching the gold from its most intimate combination with the sulphurets, and no process has hitherto been invented by which all the gold has been separated from the mineral. Experience proves, however, that by repeated pulverizations, by means of stamps and chilian mills, the aggregate amount of metal which can be obtained, is about as great below as above water.

The changes referred to in the foregoing paragraphs are true of the auriferous veins, in connection with the sulphurets of iron and copper of this country; while those containing galena are far less chemically changeable. When to the sulphurets of iron and copper arsenic is added, as in the Ducktown mines in Tennessee, the changes are still more striking.

The question whether mines are richer or poorer above than below water is not perhaps fully settled. For myself, I believe that the facts, when well determined, go to prove the undiminished value of the vein below water. But it is a question whether means sufficiently simple and cheap, can be devised by which mines can be made to pay a profit. Some will pay for forty, fifty or sixty feet, but ore may not be really rich enough to pay a profit below those points. The depth at which a vein is changed by atmospheric influence is variable. It depends undoubtedly upon the depth of drainage. It is not a point which can be determined beforehand; we may reach water in twenty-five or fifty feet, or it may not be reached in sixty; but the mean is about forty-five or fifty feet.

NOTE.—It is not designed to intimate that water has any influence in increasing or diminishing the amount of what metal it carries. The reason why the expression above or below is used is sufficiently obvious from the explanations of the text.

CHARACTER OF SOME OF THE METALLIFEROUS VEINS OF THIS COUNTRY.

§ 91. *Veins of magnetic and specular oxide of iron.* We have not as yet placed a due estimate upon the value of the iron ores of this country. The increased and increasing use of iron itself, together with the demand which grows out of our increasing population, are facts sufficiently positive and absolute to prove that the wants for this metal will soon more than double its present consumption. We have seen that our ores are abundant and favorably situated to supply the wants of the country. I need not dwell upon this topic. My object is to illustrate the formation and structure of the repositories of these ores, and in doing this I shall compare them with some of the oldest iron mines of the old world.

The magnetic iron veins are upon a magnificent scale, especially those in northern New York, to which I shall direct the attention of the reader.

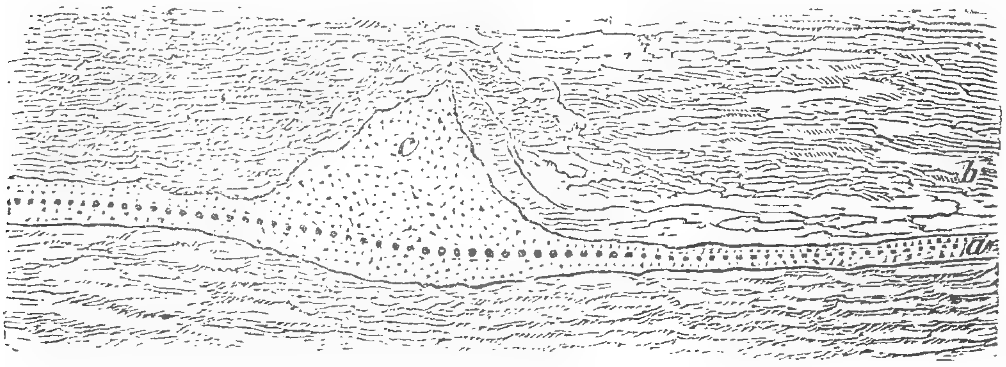
The repositories of this ore seem to be of two kinds. Of one kind I have no hesitation in saying that they are veins according to the definition usually given. Of another kind there may be doubts whether they are veins or beds, but I have regarded them as rocks or masses of magnetic iron, inasmuch as their boundaries with the rock are indefinite, and they are upon so large a scale that they are worked like quarries of marble or granite.

The structure of the veins of iron scarcely differ from those of other metals. The ore itself is crystalline, and there is no doubt but that it is pyrocrystalline. It is not subject to great changes in its composition. The veinstone, however, is often stained red or brown, by a change of the protoxide into the peroxide; such a change is regarded as a favorable indication of the quality of the ore.

In veins of magnetic iron the rich part of the ore forms a belt parallel to the walls, and it occupies very frequently the

centre of the vein. The width is variable, a mass frequently extending beyond the usual limits of the vein. The Pendfield mine in Essex county, N. Y., (fig. 26), swells out 160 feet.

Fig. 26.



The ground plan takes in this immense expansion of the vein, showing in addition the rich belt of ore by a dotted line which extends along the middle of the vein. The average width of the vein is 40 feet. Its line of bearing is northeast and southwest, and has been exposed by the removal of its covering about 20 rods, but it has been traced over half a mile.

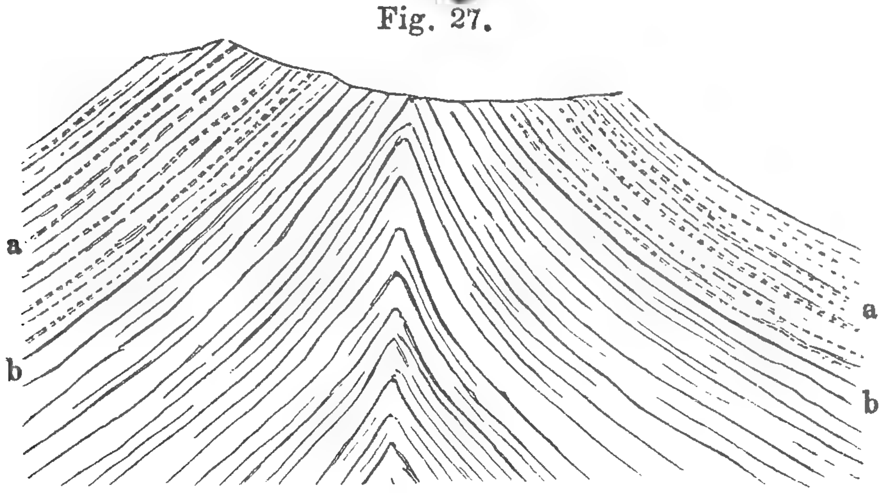
The ore adjacent to either wall is largely intermixed with quartz, while the middle is a solid mass of unmixed ore. The rock of this section is gneiss dipping S. E.; this vein of ore coinciding with the lamination of the rock.

The iron manufactured from this ore has a high reputation. It was tested at the Navy Yard at Washington, and was found more suitable for cables and chains than any iron of the country, which had been submitted at that time to the necessary tests. The superiority of this ore depends much upon the veinstone. Quartz or flint forms an admirable flux for iron, when the quantity is too great it is removed by water. There is no pyrites or phosphate of lime intermixed with it, and the forgeman has to deal with a pure oxide of iron. This ore is uniform in quality, is of dull black color, rarely bright, but crystalline and strongly magnetic. This vein has furnished ore for thirty years, but has been worked only in the forge and into blooms. The supply will be equal to any demands which are likely to be made for ore, inasmuch as it is prolonged

beyond the limits I have stated, on its line of bearing, more than half a mile from the original opening upon the tract, and another mine has been worked for twenty years, and the prospect for the permanence of ore is greater than could have been anticipated. The width of vein increases with the depth, and no fact is yet brought to light which indicates its discontinuance.

Veins of magnetic iron are distributed over limited districts. Several veins traverse this district in parallel ridges and they may be known to belong to separate and distinct veins by the dissimilarity of their ores, or of their gangues. Those which are only a few feet asunder possess unlike qualities. In deciding upon the number of veins it is necessary to guard against deception, as a fold in the strata or an anticlinal axis may place the parts of veins in such relations that they may appear to be two veins when there is only one. Fig. 27 illustrates the im-

Fig. 27.

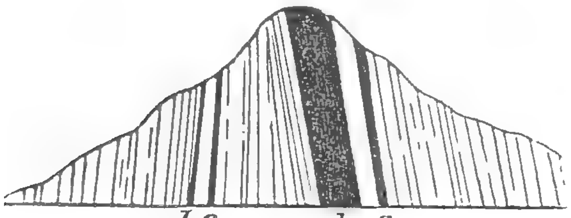


a a Vein of Ore, b b Lamina of Gneiss.

portance of being on the guard. b, b, The folded lamina of gneiss supporting a lean vein of ore, a, a, and indicated by the dotted lines. This instance is a plain one, but others of a more obscure character will not mislead the observer, provided due caution is exercised in his examination. An arrangement of veins approximating to the former occurs at the Cook mine, where an anticlinal axis seems to occur, and which might at first be regarded as a repetition of two veins, admitting that the

narrower vein is divided; but the quality of the ore and the thickness is quite different. Fig. 28. The wider vien is fourteen feet thick, and the others six, three, and two feet. These are known as the Cook veins. They traverse a north and south range. The rock is gneiss and the lamina of the planes nearly vertical.

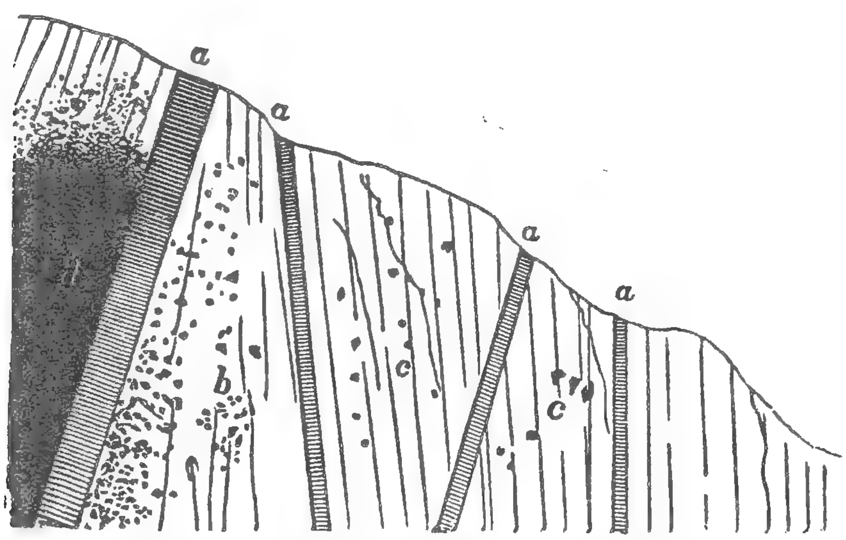
Fig. 28.



The experience which has been acquired in mining in northern New York, has now become valuable. The exploration of the magnetic ores was prosecuted at an early day, and in consequence of the adventurous spirit of the owners of mineral lands in this district, trial shafts were sunk at points which were not promising at the surface. The rock was observed to be charged with particles of ore which were found to be persistent and to have a direction correspondent with the veins which had been proved. On sinking however a shaft upon those stripes of rock and lean ore, it was found that the iron increased, and at a moderate depth, a productive vein of metal was established.

A mine widely known as the Palmer vein, is a good example of the change from a very lean ore to a rich one. A vertical section of the mine, fig. 29, illustrates the fact under consider-

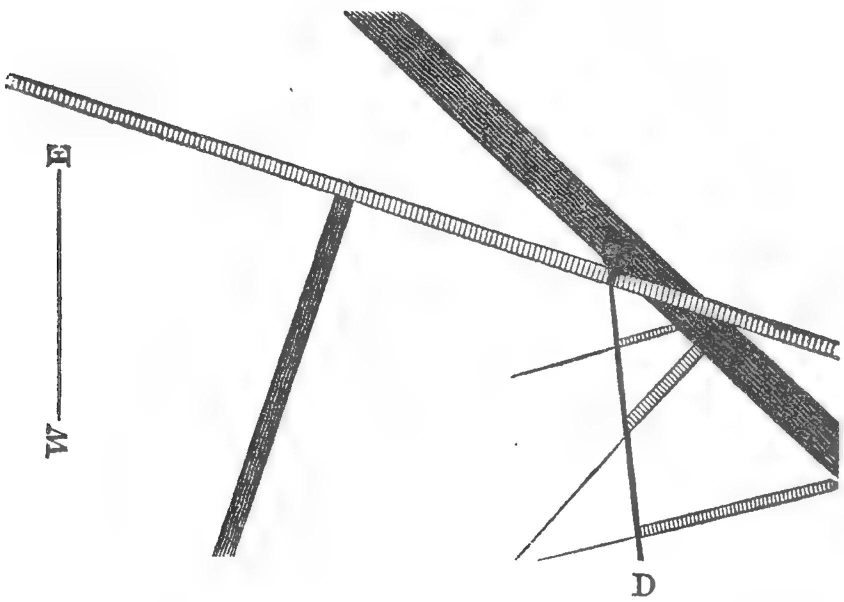
Fig. 29.



a Dykes, *b* Increased Ore, *c* Disseminated Ore, *d* Mass of Ore.

ation, and what is quite as interesting at this locality in Clinton county, is the intersection of the rock by several trap dykes. The surface of the rock is denuded and shows particles of ore disseminated through it, particularly between the dykes; a, a, dykes, c, c, the spaces in which ore is sparsely disseminated at the surface, at b, the ore increases, and at d, on the other side of the 14 foot dyke, it is a solid mass of ore, with scattering grains of gray quartz. This wide dyke cuts the veins obliquely. The ore was lean on the east side, but much better upon the west, as an adit on being cut through it, disclosed a mass of ore on the opposite side, seventy feet thick.

Fig. 30.

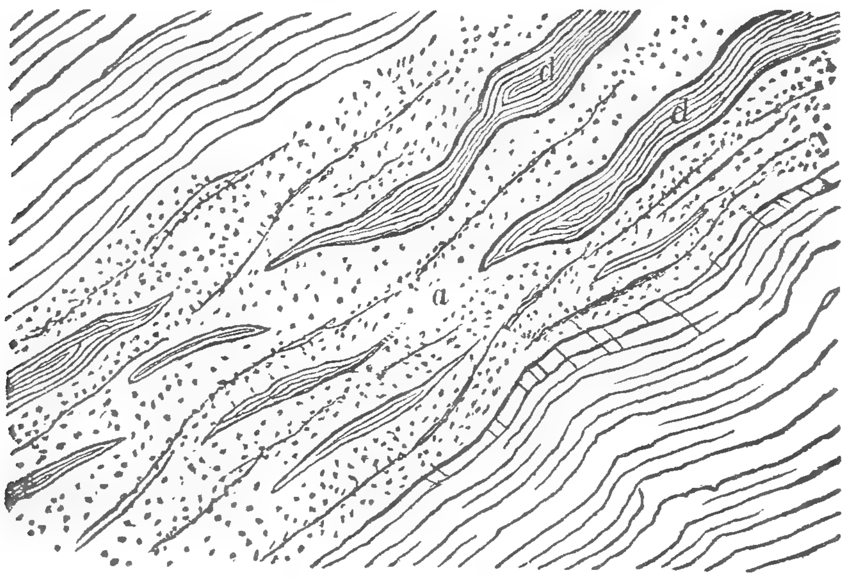


D Adit.

Fig. 30, is a ground plan of the dykes, showing their relations to the ore. These are not parallel, and as they intersect each other, they are clearly of different ages. The widest intersects the vein of ore, but the narrower ones are intersected by the latter. A, vein of ore running N. E. and S. W. B, vein of ore which runs nearly east and west. The latter is a rare example of a vein pursuing this direction. D, adit. Veins of magnetic iron often contain masses of rock in the midst of the ore which under certain circumstances have the semblance of walls. They are generally pure rock free from the ore, and as they are arranged in a direction parallel with the true walls, may, when

not examined with care be mistaken for the walls. An examination will lead to the detection of their true form which is that of a wedge. It is scarcely necessary to add that they will disappear in the progress of mining.

Fig. 31.

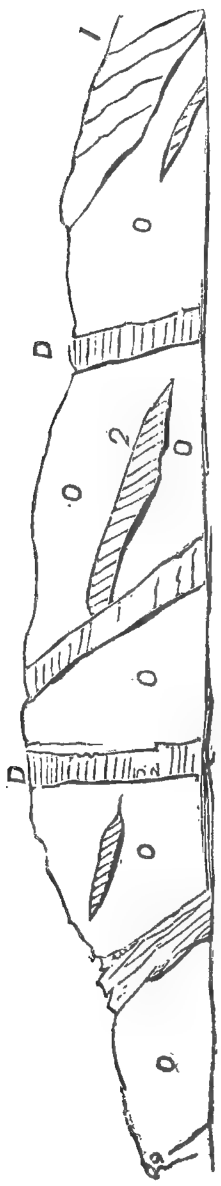


a Ore, *d* Quartz.

Fig. 31, illustrates the fact I have just stated. It is a section of a part of the Hall vein, in Moriah, Essex county, the parallel masses of rock, are, d, quartz, a, ore; but they may consist of hornblende or feldspar. An interesting instance of the same kind, is now being exposed at the Old Sanford ore bed, where masses of trappean rock and feldspar, are intruded into the midst of the ore. Fig 32. In this instance the strike of the vein is not determined, and hence it is impossible to say whether these masses are parallel with the walls or not. Each of those masses might be regarded as limiting the ore, but on cutting through them, equally good ore is found in the spaces between the dykes, as at any other part of this remarkable vein.

Since the foregoing was penned, I have ascertained, by an examination of the wall, that three of the dykes have disappeared, and the three obliquely placed masses of rock are entirely removed, and there now appears a breast of solid ore 146 feet long and twenty-five feet high, traversed by a single dyke

Fig. 32

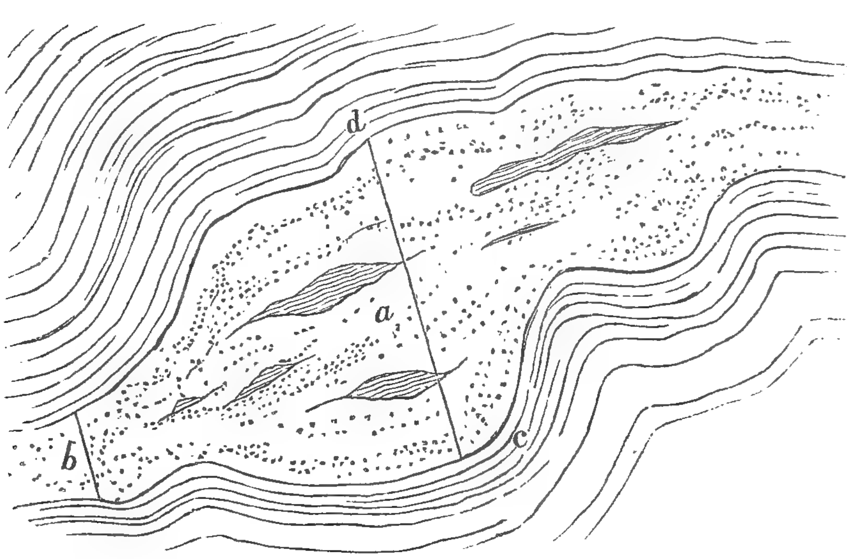


o o Ore, D Dykes, 1 Gneiss, 2 Rock.

twelve inches thick. The dykes are composed of a greenish, foliated crystalline feldspar. The disappearance of a net work of nonmetallic veins, is by no means an uncommon circumstance in mining in Northern New York, and hence there is encouragement in mining of this description, that the dead work will diminish as it progresses. The gangue of this ore is phosphate of lime, in small reddish particles, imbedded in the grains of the oxide. They are usually of the size of a kernel of wheat. When the phosphate is separated, the iron made from this ore is good, but if manufactured with the phosphate it is brittle. This mineral constitutes about one-fifth of the mass—but in parts of the vein it is equal to one-half of the mass of ore. The phosphate is now separated by magnetic separators, is ground and prepared for use in agriculture.

Adventurers in mining are often startled on finding the vein diminishing in width. In iron mining, however, those fears are

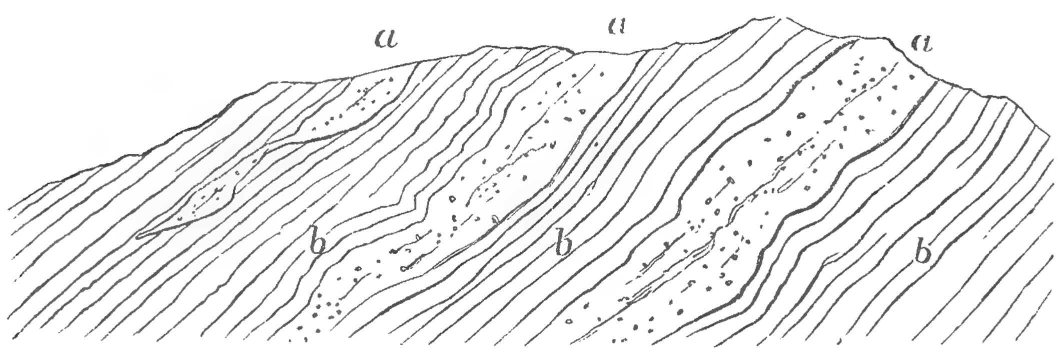
Fig. 33.



b Constricted Part of the Vein, *c* Gneiss.

groundless. When the Hall mine was first opened, it enlarged to eight feet. Afterwards it diminished rapidly to less than four feet. Fig. 33, is a section of this part of the vein. It was eight feet wide at a, a, and when I examined it in 1837, it was pinched out to four feet. At this stage of the working it was a question what would become of the vein. On pursuing it farther and into the constricted part, it began to widen again, and has proved to be one of the most valuable mines in the Moriah mineral district. It has been worked to the depth of a hundred feet. The vein appears inexhaustible. A transverse section of this district, about one hundred yards, furnished at least three parallel veins. The annexed section was made in 1837, fig. 34, a, a, veins, b, b, gneiss. All of these have been proved

Fig. 34.



a Veins, *b* Gneiss.

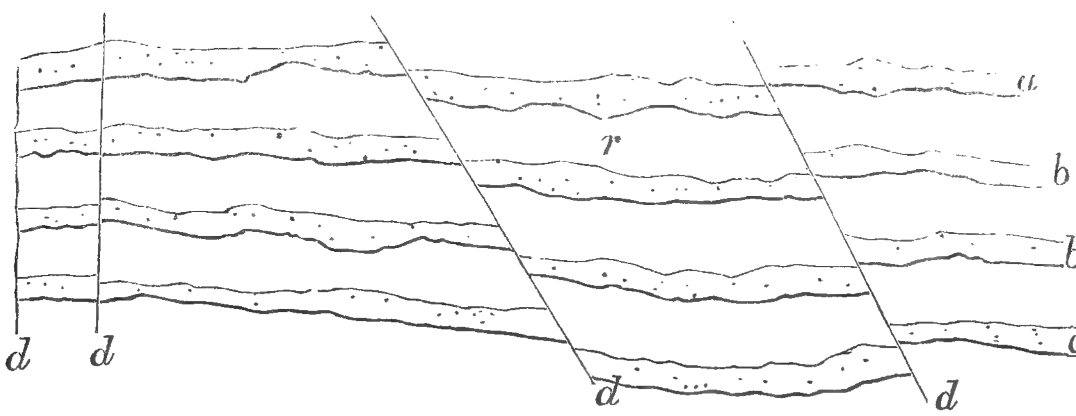
to the depth of seventy or eighty feet, the ore increasing in richness with the depth. They have been traced about one and a half miles. Their line of bearing is northeast and southwest, and they dip with the plane of lamination of the gneiss in which they are inclosed, and half a mile west of the Sandford mine, they have been extensively worked, and yield a pure black granular oxide. Phosphate of lime is not present in the three parallel veins, although in the immediate neighborhood of the Sandford mine which is so rich in it.

The veins of magnetic iron contain ore whose quantities differ materially from each other. No two veins, however near, supply the same kinds of ore. A good example and one in point, are the well known veins in the Clintonville mining dis-

trict. Four veins have been worked to a depth from one hundred to two hundred and sixty feet. These occupy a high hill four miles west of Clintonville. The first vein which was opened contained a beautiful blue and irridescent ore, both soft and granular. The next vein which is parallel with the first, furnishes a black ore, and the others a gray ore. The blue ore probably makes the softest iron of any ore in this country. The others a harder iron. The first is from four to eight feet wide, and the direction and dip of the four correspond, being north-northeast, and dip west-northwest, at an angle of 70°. The ore of all of these veins has been changed from that of a protoxide to a peroxide, as they all give a red powder, but the change is more descisive in the blue vein. The gangue is a blue gray quartz in the gray veins.

These veins have been shifted simultaneously by dykes in a

Fig. 35.



a b c Metamorphic Peroxide of Iron, *d* Dykes, *r* Shifted Parts.

mode represented in diagram No. 35, d, dykes, a, b, b, c, four parallel veins of metamorphic peroxide of iron.

About half a mile north of Clintonville, a mine worthy of a passing notice was opened at an early day. It is known as the Winter ore bed. The ore is hard, but being pure, it made a good iron, and as it was situated conveniently, it was desirable to make the most of it possible. The vein reposed upon the top of the rock, and it excited attention from the novelty of its position. It was in the form of a flat superficial

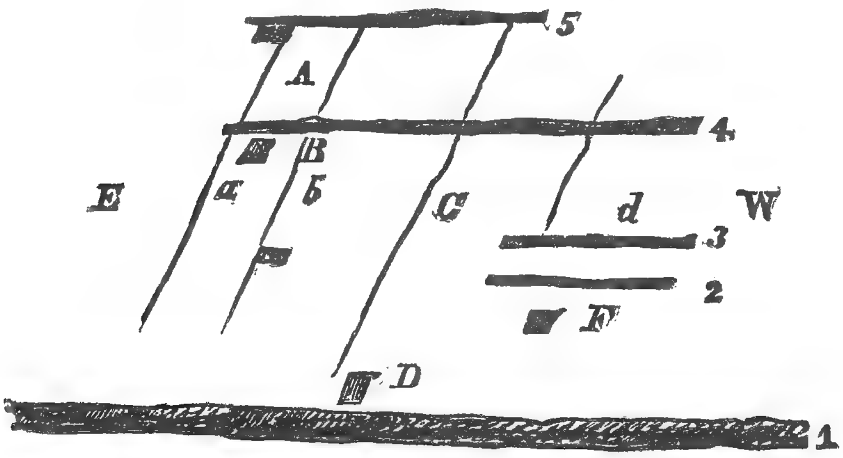
mass gently inclining to the north; this mass was about a hundred feet long and forty wide. It was all quarried out, and when this was done, the miners lost all trace of its direction. Several shafts were sunk in hopes of striking some parts of the mass or veins which it was supposed might be prolonged beneath and between the lamina of the rock. These were all unsuccessful. The following diagram illustrates the relation of the vein to the rock, fig. 36, a, a, a, a, masses of ore, a is the

Fig. 36.

a Masses of Ore.

large mass already referred to. These five masses are regarded as parts of one vein, interrupted and broken at the time of upheaval, presenting a very imperfect anticlinal axis. The mass a forms the crown, but being unsymmetrical and the others being lean their true relations had been overlooked. The dip on one side is to the east, and on the other to the west. The plan proposed for recovering the mine or vein was to tunnel from the eastern slope with a view of intersecting it, two hundred feet below the surface. The plan was adopted and the vein recovered. The complication was increased by numerous trap dykes. No less than seven crossed the mining tract in about two hundred feet. In diagram 37 the dykes and

Fig. 37.



1 2 3 4 5 Dykes, *A B C d* Parts of the Vein.

parts of the vein are represented. 1, 2, 3, 4, 5, are the parts of the dykes which appear to have produced shifts in the vein, or rather the irregularities, we may suppose, in the anticlinal axis are due to their presence. The dyke No. 1, is twenty-seven feet thick, and in tunneling it was proposed to cut it along this dyke. The cost of tunneling was five dollars per linear foot, with an adit six feet high and five feet wide.

A vein at the outcrop sometimes has a less dip than in the earth; and when the vein is flat, as it may be, the inexperienced are very likely to overestimate the width of the vein. The Averil vein at Clinton prison, was nearly flat for forty feet. It had been worked from its easterly outcrop to the west, and along its strike about one or two hundred feet in length. At a point about forty feet to the west, it showed at first, an inclination to the west, and then began to dip more rapidly—when uncovering it still farther west, the hanging wall was discovered. For more than forty feet this wall had been removed, having a flat mass of ore from fifteen to twenty feet thick. The position of the vein was calculated to deceive those who were or might be interested in the property respecting the quantity of ore at this mine, or near the surface.

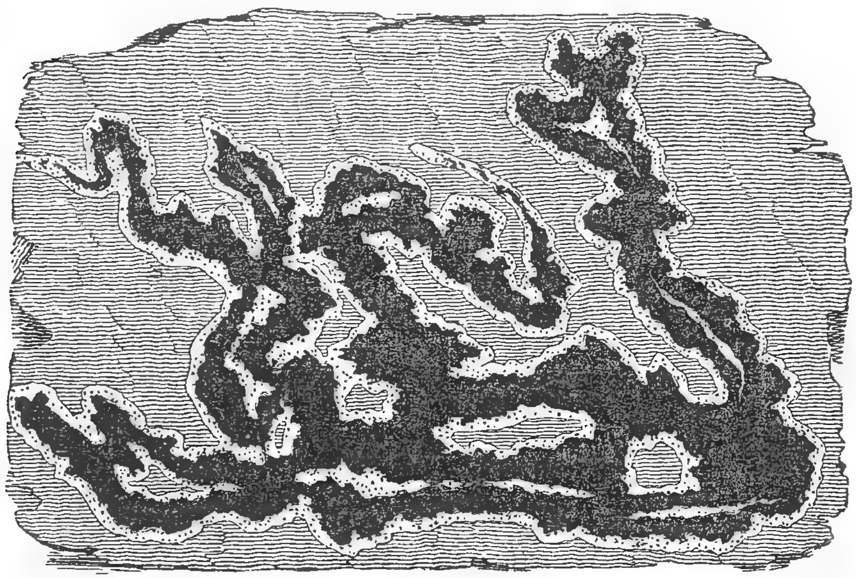
The illustrations and remarks which I have made respecting the iron ores of Northern New York, are applicable to all those which lie upon the base of the Appalachian range, from north to south. I have already referred to the numerous veins of this ore, and have spoken in general of its value and extent. The resources for the supply of iron in this country have never been properly estimated. We may, however, expect that for the future the attention to the manufacture of iron will be turned more exclusively to our means and resources, and that necessity, as well as interest, will soon establish for the iron manufacture what has already been established for cotton.

The iron ore of the western part of Essex county, N. Y., lies in immense beds, or rather constitutes rocks of no mean extent. We are unable to discover that it is enclosed in regular walls, though rock bearing a resemblance to walls is often encountered

in the midst of the ore. The ore of Sandford lake, at or near Adirondack, may be cited as an example of a huge mass of magnetic ore in the midst of hyperthene rock, whose boundaries have not been determined. It is between 700 and 800 feet over, measuring from east to west. It extends still farther, but the debris and soil is too deep to admit of removal for the single purpose of disclosing the extent of the quarry of iron rock.

The masses of ore at Adirondack frequently extend into the adjoining mass in branching or ramifying veins, which usually terminate in threads or strings, and are therefore lost in the rock. At certain points, as I have already remarked, the ore rests against the rock, which appears like a wall, but it has been observed in many instances, that on penetrating beyond this apparent barrier, the ore is found extending beyond it. The extension of veins into the hyperthene rock is illustrated in fig. 38. Garnets border or fringe the veins lying between

Fig. 38.

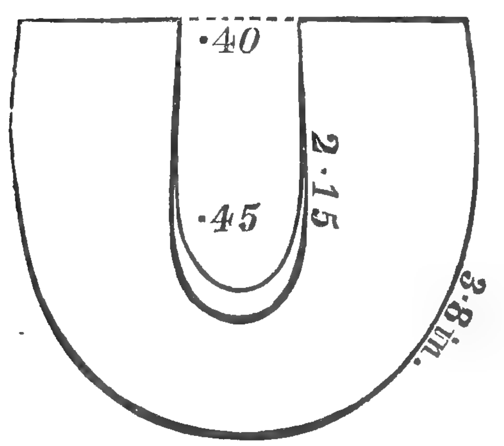


the rock and ore. These garnet borders seem to have been produced by the influence of the ore upon the rock.

The ore of Adirondack produces a remarkably tough iron. In the Catalan forge the result is too uncertain, and it does not furnish when reduced in this simple way, an iron the qualities of which are constant; yet bloomers of intelligence have suc-

ceeded in making from it iron whose qualities were equal to the best Swedes iron. Many samples of this iron have been tested at different times and by different modes, all of which tended to confirm the favorable opinions entertained respecting the value of this ore. The late Prof. Johnson's tests were the most satisfactory which were made. The iron could be drawn to an half inch bar under the common trip hammer, and bent when cold without breaking the fibres, or producing cracks. The bent bar represented in fig. 39 illustrates in the most satisfactory manner, the quality of the iron which may be made from this ore, both as regards toughness, and durability. The outer curve of the bar is 3·8 inches in length, the inner only 2·15 inches. The length of this bar before it was bent, was $2\frac{1}{4}$ inches; the width 1·29, and the thickness 0·59.

Fig. 39.



The specular or peroxide of iron takes the place of the magnetic, in Jefferson and St. Lawrence counties, N. Y. The associated rocks of the St. Lawrence side of the mountains differ somewhat from those of the Champlain side. Gneiss, granite and pyrocrystalline limestone belong to both sides, but on the Champlain side the former rocks contain the magnetic ores, while the latter on the St. Lawrence side contain the specular. Serpentine is also a constant associate of the latter. There is really no difference in the mode of occurrence of the two oxides, both are primarily in veins. The specular oxide, however, may appear to be an exception, as a very large proportion of the ore of Jefferson and St. Lawrence counties has been obtained from beds in the soil. The ore, however, is derived from veins. Its constitution favors its disintegration. The associates of the specular ore are crystallized quartz, mostly in dodecahedrons, carbonate of lime and magnesia, carbonate of iron, sulphate of barytes, sulphuret of iron, cacoxenite, sulphuret

of nickel. The last two are rare. The ore, except when broken down or disintegrated, is in crystals and crystalline masses, with brilliant surfaces—and in this condition is very pure and free from sulphuret of iron. The veins lie in parallel position with the lamina of rock, where they can be traced to rocks of that class; when in serpentine or limestone the ore is apparently in masses, and may be removed entirely from the rock. The specular ore is not confined to pyrocrystalline limestone; several veins, as the Polly and Tate ores are subordinate to gneiss, but maintain a connection with serpentine. The Kearney and Parish veins are important ores, and extend for two or three miles in a northerly direction.

Magnetic ore occurs at one or more localities in St. Lawrence county, in the township of Chaumont. The ore is rich, and being situated upon the Oswegatchie, and in a well wooded forest, will in time become a valuable location for the manufacture of iron.

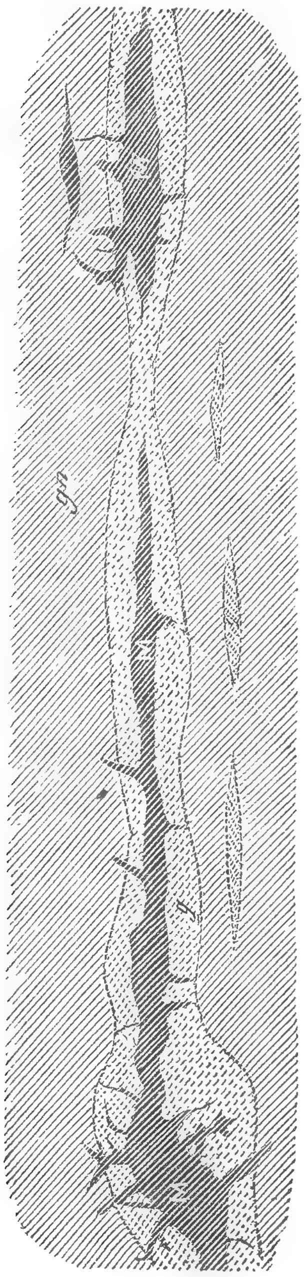
From the foregoing remarks and illustrations, it is apparent that iron ores do not preserve those geological relations which are absolutely similar in all parts of our country. While we may observe, however, considerable diversity in their occurrence, still there is such a general similarity in those respects, that we may avail ourselves of the use of general principles in conducting the necessary mining operations. This general similarity extends also to the conditions of the great masses and veins of ore which are best known, and which have been the most extensively worked in foreign countries, particularly those of Norway and Sweden.

The annexed diagram, fig. 40, copied from a valuable article on the mines of Arendal,* would illustrate our own mines of magnetic iron. It is a ground plan; M M, masses of ore prolonged in the direction of the vein, but variable in width and apparently interrupted; *gn* gneiss, *g* limestone. This vein branches out into the walls of the gneiss. It occupies a middle part of

*Annales Des Mines, Tome IV, 1843.

the fissure, a fact which is quite constant in our own mines. A vertical section of the mines of Arendal exhibits similar arrangements to the mines of the Appalachian range. Indeed, the phenomena are so constant that only a few illustrations are required to exhibit all the most important facts relating to the veins of magnetic and specular oxides of iron. The relations and circumstances under which these ores occur, seem to point to their igneous origin. In numerous instances minerals of contact are developed, such as garnet, hornblende, epidote, &c. In this respect the action of these ores resembles that of other pyrocrystalline rocks. Garnet and epidote appear to be the most common minerals which are developed under circumstances similar to those under consideration. Of the two, epidote is the most common: it accompanies the numerous varieties of porphyries, appearing in different stages of development, from a mere yellowish coloring of the rock in patches, to perfect nests of crystals. The slaty rocks of sedimentary origin, frequently furnish this mineral in all the different stages referred to. In the case of garnet, its development usually takes place contiguous to the mass of igneous matter, while epidote is found more extensively and widely diffused in the rock.

Fig. 40.



M M Masses of Ore, *gn* Gneiss, *g* Gneiss, Hornblende, and Garnet.

LIMONITE OR HEMATITIC ORES OF IRON.

§ 92. The geological position of this ore in New England and New York is not well determined; but when in beds it seems to be enclosed in materials very similar to drift. But the drift beds have been derived from distant places; and as the rocks are rarely uncovered, it has been up to this time an unanswered question, where this ore belonged. At Adams, Berkshire, Massachusetts, the ore has been traced apparently to a vein in the quartz rock, near its junction with mica slate of the Hoosick mountain. Farther south, in Maryland, Virginia, and North Carolina, limonite occurs in veins. The most conclusive facts bearing upon the geological position of limonite have been disclosed in Cherokee county in North Carolina, in the vicinity of Murphy. It occurs upon the surface, rising up like mounds which cover several acres. When it had been observed at the copper mines in Ducktown that this kind of ore covered the black oxide of copper, those mounds were explored by cuts and shafts in expectation of finding copper. Though these explorations terminated in disappointment, yet it was discovered that those mounds of iron ore surmounted a vein which, near its surface, was composed of gossan mixed with sulphuret of iron, but no copper. In all those cases where gossan was cut entirely through, the back of the vein was found intermixed with sulphuret of iron only. I was quite satisfied that the prospect of finding copper was too uncertain to warrant the prosecution of the object when the expenses were likely to become considerable.

The accumulation of mounds or masses of the hydrous peroxide of iron or gossan many feet beneath the surface, is owing, first, to the ordinary decomposition of veins of sulphuret of iron, and the breaking down of the rock as the process proceeds; and the debris remains, as the country in this latitude has never been subjected to causes which disperse and scatter it abroad after the decomposition. At the north, how-

ever, embracing the Canadas, New England, New York, and Northwestern States, as far south as Cincinnati, diluvial action has removed the loose materials south, southeast and southwestward. Hence the hematites are buried deeply in drift, often having been lodged in protected positions. The bog ores are accumulations of the hydrous peroxide of iron in swampy depressions. Instances of bog ore upon hillsides and in dry places, are not exceptions to this statement: they are beds which have been elevated by subterranean forces. Examples of this kind occur in Jefferson county, New York. They contain the leaves, trunks, and roots of trees now living. In the neighborhood of the elevated beds of bog ore the rocks have immense pot holes; and connecting these facts, the conclusion is forced upon us, that the country has been elevated during the modern period. Bog ore is also formed from the decomposition of the sulphuret of iron, which is disseminated in rocks which undergo disintegration and decomposition. Water bears the materials into the depressions, where, in time, thick beds accumulate.

THE GOLD-BEARING ROCKS OF THE UNITED STATES.

§ 93. In this country, both in its mining districts and in its general geology, we have sought to discover and make out similitudes or analogies with Europe, rather than to discover the grouping and relations of our rocks, minerals, and fossils. Our attempts have been made rather to compel facts to bow and obey what has been represented to exist abroad, rather than to give them the independence they deserved, or to honor them by the deductions they sustain. Our gold, copper, and lead are associated with minerals differing from those of Cornwall or the Hartz. Our copper of lake Superior has no parallel in European mines. Every day's experience proves that the metals have associations more general than has been represented; that they are by no means confined to one rock and one geological position. It has been supposed that the

gold of this country was confined to talcose slate. This is now known to be untrue; for, in addition to talcose slate, it is found in mica slate, hornblende, granite, and limestone. It has a wide range of relations, and it would seem that the metals have geographical rather than geological boundaries; that is, in a given district all the rocks may be expected to contain them; or, in other words, that there are certain types of association which belong to certain geographical districts, and that in order to pursue successfully mining interests, we must study that type. The doctrine, however, holds good, that a certain rock is commonly the bearer of a given metal rather than any other.

In this country quartz is the common associate of gold. But other associates may exist: the massive talcose slate, hornblendic gneiss, hornblende, granite, mica slate, limestone, and even serpentine. In talcose slate, gold may be disseminated in the rock for from forty to sixty feet in width. It is a mass of rock, or a mass mine, which bears no semblance to a vein, except that belts or strips of it are richer than others; but it is impossible to detect walls or defined boundaries to the auriferous parts. The gold of the mass is mechanically mixed with particles of a brown substance, disseminated in the rock sufficiently abundant to impart red and brown tints to the mass. These are sometimes of a rosy or peach-blossom color, indicating the presence both of iron and manganese. There is no doubt that these brown and reddish particles were sulphuret of iron which held the gold in mechanical combination. Where the auriferous mass is inspected, it is found to consist of fine grains of quartz, which are only slightly coherent, intermixed with silvery talc, which at the first inspection seems to predominate, but on closer observation proves the predominance of quartz in its composition. This kind of rock might with propriety be called *talcite.*

Gold is also disseminated through a pure saccharoidal quartz, which contains neither sulphuret of iron or talc; but this white and pure quartz may be contained in a vein or mass subordi-

nate to that just described. It is found again in milky and granular quartz in veins, carrying the sulphurets of copper and iron and sulphuret of iron by itself, together with galena, and sometimes sulphuret of zinc. These veins may traverse argillaceous chlorite and talcose slates, or all the other rocks which belong to the mineral district, as gneiss, hornblende, or granite. In the last place it may be contained in a false vein, or rather beds, as the depositions are parallel with the strata or lamina. They are always thin, rarely exceeding twelve inches in width. The metal in this case is confined to a well defined strip of rock, but not limited by distinct walls. The eye can not detect a difference between that portion of the rock which is auriferous and that which is not. These false veins or beds being narrow, may be lost, unless the miner resorts constantly to the use of the pan for testing the presence of gold. These strips are usually very rich, and often yield from twenty-five to one hundred dollars per bushel of ore.

The gold of the soil is derived from rocks broken down by the ordinary atmospheric agents. In its dissemination in the soil, it has obeyed the same law of distribution as all the bodies which have great weight. As its gravity exceeds that of all other substances which may be expected in the soil, it will be sought for at the lowest planes of subsidence.

Leaving out of the account the gold deposits of the soil, it is most frequently found in the regular veins, associated with the sulphurets of copper and iron. It is probable that the sulphurets should be regarded as the true matrix of gold, though not the only matrix. The veinstone is quartz, though in a hundred auriferous veins of quartz containing sulphurets, one or two are known in limestone, and occasionally also it has been found in serpentine.

The veins of auriferous quartz do not differ in structure from other veins; and they are subject to the same irregularities in width, and the same varieties as to richness in parts of the vein, both when examined in the line of bearing and in depth.

OF THE CHANGES WHICH TAKE PLACE IN THE AURIFEROUS VEINS OF SULPHURETS OF COPPER AND IRON IN DEPTH.

§ 94. The condition of the materials at and near the surface differs materially from that below. Those sulphurets which are gold-bearing seem to be more subject to decomposition than those which are not. At a variable depth, then, the matrix of gold consists of a porous quartz, colored brown upon the surface by a superficial deposit of oxide of iron. This partially fills the cavities. It is a friable dry powder, or it may have become consolidated, in which case it resembles the oxide of iron with a resinous luster, or the common brown hydrous oxide of iron, or brown hematite. This condition of the iron is due to the decomposition of the mixed sulphurets of iron and copper. The sulphur is discharged, and usually disappears entirely, and leaves the rock; but not always, for in a few instances it is retained in the cavities, and has crystallized in octahedrons with rhombic bases. The decomposition proceeds from the outside to the inside, as the inside of a mass of oxide often contains an undecomposed one of sulphuret of iron or copper. Where the decomposition is complete, the gold is attached to the quartz in irregular plates, or is also retained in the midst of the oxide in grains or thin scales. But it is a still more interesting fact, that the gold occasionally crystallizes, and appears under the form of octahedrons and dodecahedrons, or in skeleton crystals, the general form of which is developed, but the faces are deeply striated. Beautiful productions of this kind were quite common for a time in the Ward mine in Davidson county, North Carolina. The figure of one of these striated or skeleton crystals appears on the title page of this work. Regular octahedrons have been obtained in the mines of Burke county in the same state. But crystals of gold are extremely rare in North Carolina.

ORIGIN OF GOLD—THE GEOLOGICAL POSITION AND RELATIONS OF GOLD.

§ 95. If we attempt to account for the origin of gold on facts and principles which are inapplicable to the origin of other metals, we entirely lose ourselves in conjecture. Indeed, the phenomena which accompany the auriferous quartz veins are by no means unlike those which accompany lead, copper, and iron. Its subterranean origin should therefore be admitted.

The gold of North Carolina is connected with three divisions or sections of rock: 1. With granite and associated rocks; 2. Gneiss and its laminated associates; and 3. With a series of slates which I am disposed to regard as sediments. The immediate repository of this metal is the ordinary constituted vein, differing in no respect, in its structural relations and origin, from those of the other metals and ores. It will be observed that I have passed unnoticed the deposits of gold in the soil and grits of decomposed rock for obvious reasons.

The slates are soft, greenish or reddish rocks, intersected by quartz veins and trap, and appear to repose upon granite so as to admit the outcropping of low and long ridges of this rock where the slates have thinned out. The rock, however, which I have noticed under the general name of slate, is really made of a series of rocks, which furnish a series of subordinate beds which have a wide range of lithological character. The following is a list of the most important kinds: 1. Soft green chlorite slate; 2. Soft red, reddish, and purple and purplish slates; 3. Soft talcose slates, which contain, however, quartz in fine grains, and which are also reddish and purplish. This variety might receive with propriety the name of *talcite* as already proposed. Alternating with the foregoing soft slates are the harder masses, which consist of

1. Quartzite, a mineral which in all respects resembles chert or hornstone. It is whitish, green, bluish, passing into black, and often coarsely agatized. It breaks with a flat conchoidal

fracture: it has sharp and translucent edges, and is usually very tough. When mixed with a small proportion of argillaceous matter, it forms also a hard tough rock, which appears above the surface of the ground in hatchet-shaped projections. Sometimes these rise, with rounded, sharp edges, seven or eight feet high, and extending as many feet in the direction of their strike, and then disappear in the soil. A succession of such outcrops continue for miles, forming a peculiar feature in the geology of the district.

2. A quartzite porphyry. This rock is quite common. Its porphyritic character is obscure; and it happens not unfrequently that it takes on the character of a breccia. Fig. 22 is designed to illustrate its porphyritic character; but it is often more obscure, and I am well convinced that I have found a few rolled quartz pebbles imbedded in the mass.

The quartzite or chert is in beds, and in one or two, and probably more districts, composes the largest part of the rock in a belt half a mile wide. It appears homogeneous in the protected part of the mass, while the weathered surface consists of a white or gray fine granular substance, similar in its condition to tripoli. This change extends several inches into the rock, and forms a well defined border around the unchanged parts within the mass. Although the slates bear strongly the indications of sediments, no fossils have as yet been found in them. In their general features they bear a strong resemblance to the slates of the lower half of the Taconic system. I do not propose to attempt to give a full and minute description of this formation of slates of North Carolina, and of the adjacent states, at this time. I shall proceed to the consideration of certain questions relating to the gold as it occurs in veins, and other relations to the rocks which contain it.

COMPARATIVE RICHNESS OF THE UPPER AND DEEPER PARTS OF THE VEIN.

§ 96. The opinions of miners, as well as geologists, do not agree on this question. The facts sustain apparently the doctrine that the yield of gold diminishes where the vein is beneath water. When the facts, however, are carefully examined, they are not so decisive of the assumed position. The mine which is of all others most reliable in North Carolina, is the Gold Hill mine. Its depth is about five hundred feet; the vein quartz, bearing the sulphurets of copper and iron, and the rock, a greenish slate. The upper forty or fifty feet of the vein was decomposed, and of course the gold easily obtained. Different companies had leased parts of the vein. One company worked upon a level between one and two hundred feet from the surface; another company worked a three hundred feet level down to four and five hundred feet. Now, while the vein did not yield profits at all large at the upper level, the lower was very profitable; even twice the amount of gold was obtained in the deepest part of the mine.

The opinion that a gold mine is less rich in the lowest levels or below, arises from the state of the metal, or from its combination with the sulphurets; and experience has proved in thousands of instances that it is extremely difficult to separate the gold by the mechanical processes usually resorted to. After the ore has been subjected to one operation, and all the gold apparently obtained from it, and this fine material is allowed to remain a year or two exposed to the air, and then worked again, it will usually yield by the second process nearly as much gold as was obtained by the first; and so the same ore may be worked five or six times, and made to yield profitable returns of gold. These facts are especially applicable to the auriferous sulphurets. It appears then from experience in North Carolina, that the auriferous veins are equally rich below and above water, to use the common comparison, and that there is

no diminution of gold in the deeper parts of the vein. Like other veins of metal, it is variable in quantity—rich and lean places are met with in the same mine; but the Gold Hill mine, the McCulloch mine, Conrad Hill, and all those which have been skillfully worked, yield as much gold now in the aggregate as when they were first opened. It must, however, be acknowledged that though the quantity of gold obtained below water may equal that above, yet the increased expense of mining may consume all the profits of the business, and, in many cases, prudence would suggest the abandonment of deep mines.

DIRECTION OF THE AURIFEROUS VEINS.

§ 97. The extremes in the direction of veins lie between N. 10° W., and N. 70° E. The ordinary limits lie between N. 20° E. and 70° E. Their direction of dip is northwest in North Carolina, and the angle of dip varies from vertical to 20° at the surface, while where it is as small as 20°, the dip becomes greater in its progress downwards. The ordinary dip is such that a vein will make to the westward seven or eight feet in seventeen or eighteen feet perpendicular descent.

OF THE AURIFEROUS VEINS WHICH PASS FROM ONE ROCK TO ANOTHER, AND WHOSE COMPOSITION AND AGE ARE DIFFERENT.

§ 98. In North Carolina a belt of granite underlies parts of Guilford, Davidson, Cabarras, and Mecklenburg counties. The east side of this granitic belt is bordered by a fine greenish slate. It is the opinion of well informed miners and geologists that the auriferous lodes pass from the granite into the slate. The observations have been made where the slate is thin, and overlaps the granite. Fears were entertained that certain lodes would become valueless for gold when they entered the granite, agreeably to a law which is well established in other mining districts. My opportunities for observation are too limited to warrant the expression of an opinion; but I have

been informed that in two or three instances the lode has not deteriorated after it has left the slate and entered the granite. The question, however, it appears to me, is not yet satisfactorily settled.

Of the age of this slate I have as yet been unable to form an opinion. In certain localities its character favors the view that it is a sedimentary rock. But so far as I can speak from observation, it is not fossiliferous, and it is doubtful whether it contains rounded pebbles. The only slate rocks which resemble it are situated above the quartz rock of the Taconic system.

AGE OF THE AURIFEROUS VEINS OF NORTH CAROLINA.

§ 99. The idea which has gained a few supporters, that gold is of recent origin, does not seem to be sustained by facts. President Hitchcock,* for example, quotes approvingly the opinion of Sir R. A. Murchison, that gold is of a recent origin; as late, for example, as the tertiaries. Opinions of geologists whose reputation is so widely spread should not be set aside for slight reasons. We find, notwithstanding the high authority to the contrary, that the permean rocks of North Carolina contain the debris of the auriferous quartz veins: the gold itself may be obtained from the quartz in the usual way. Whether the auriferous rocks of North Carolina and Virginia belong to the same period as those of Australia is not determined. But that the Carolina gold rocks and those of California belong to the same period, there is scarcely a doubt. An interesting fact connected with this subject should be stated in this place. In Burke county, North Carolina, E. Emmons, jr., discovered pottery and implements supposed to be of Indian manufacture, such as arrow heads, in the auriferous quartz grit seven feet below the surface. The grit is overlaid with a stiff clay. So the mammoth remains are found in Siberia in the same alluvia that contain gold.† These facts do not prove the recent origin

* Geology of the Globe, p. 31.

† Idem, p. 31.

of gold, neither can they be employed to prove that a change of climate took place about the time the Mammoths of this country became extinct.

I have already had occasion to state the facts relative to comparative richness of the gold veins at considerable depths. This question is economically one of great importance. Capitalists in this country are now pursuing their schemes and plans for working gold mines at all accessible depths. They make no distinction between auriferous and cupreous veins, neither do the auriferous veins appear at all analogous to the staniferous veins of Cornwall, which were said to be staniferous upon their backs, but cupreous in the main parts of the lode. Here the gold accompanies the yellows, as the sulphuret of copper was called in Cornwall, without giving place to it as the tin lodes referred to.

AGE OF THE GOLD BEARING ROCKS OF THIS COUNTRY.

§ 100. The talcose slates, mica slate, hornblendic gneiss, etc., which are traversed by auriferous veins, belong to a period which preceded the deposition of all the hydroplastic rocks of this country. The evidence which sustains this position is of two kinds. 1. Evidence of composition and derivation. 2. Of superposition and succession.

1. The oldest sediments belong to the Taconic system. The talc and mica of the gneissoid granite enters into the composition of the limestone. A peculiar bluish tinted quartz of the same rock enters into the composition of the quartz rock at the base of the Taconic system. These minerals are distinguishable from other varieties of the same species. So it is not less certain that the materials of the Taconic system are carried up into the Silurian. Thus a stratified limestone is found in the Potsdam sandstone at Chazy. The Taconic slate enters into the composition of the lower part of the calciferous sandstone.

2. The quartz rock of the Taconic system rests unconformably upon the gneiss of the Green Mountain range, or its gneiss-

oid granite, at many places; and the Potsdam sandstone, or in its absence the calciferous sandrock, rests unconformably upon the Taconic slates and other members of the same system. The auriferous rocks, therefore, are inferior to two systems, and the lines of demarkation between the systems are so distinctly drawn, that they should not be overlooked. There is no evidence that the lower Silurian are metamorphic rocks, which contain the gold of this country, though this veiw is taken by a distinguished geologist in the governmental survey of Canada.

Several rich auriferous veins traverse a hornblendic gneiss in Rutherford, N. C., at the eastern base of the Blue ridge. On the west side of the same ridge gold is derived from mica slate, four miles west of Sowannanoe gap. I entertain the opinion that we have no facts which sustain the doctrine that the rocks of the Blue ridge are altered Hudson river sandstones and shales, and yet the Blue ridge, where it is auriferous, is identical with the Green Mountain range.

DISTRIBUTION AND EXTENT OF THE AURIFEROUS ROCKS EAST OF THE MISSISSIPPI VALLEY.

§ 101. We can not with certainty determine the extent of the auriferous belt of the Atlantic slope. Its width in North Carolina is at least one hundred miles on a line, passing through the state from southeast to northwest; but the area over which gold has been found, is equal to 10,000 square miles. It is found in this state, in all the counties lying west of Wake, and is from fifteen to thirty miles wide in Virginia. One gold vein only is known in Maryland; but the slates which usually contain gold are about ten miles wide. The gold vein in Maryland is at Brookville, in Montgomery county. Gold is not found in this direction until it appears in Somerset, Vt., on the east side of the Green mountains. All that is interesting at Somerset is the fact that gold occurs in the same relations as at other places in the South. Still farther north, in Canada East, it reappears again, at Sherbrooke and La Chandiere river. It is associated

with quartz, as usual, but the most productive locations are the deposit or branch mines. The indications bear a favorable aspect in the Canadian mines. From North Carolina, the gold belt extends south through South Carolina and Georgia, disappearing at last beneath the tertiary of the Atlantic slope.

OF THE PYRITES AND AURIFEROUS COPPER LODES OF THE ATLANTIC SLOPE.

§ 102. There are classes of gold mines in which copper is rarely if ever found. There is first the disseminated gold of the soft slates. When the metal is widely diffused in the rock, the produce amounts to from ten to thirty-five cents per bushel of ore. These masses of slate may yield gold through a width of one hundred feet; some places are richer than others. They may be called mass mines. In auriferous rocks of this kind, the gold is combined with very small particles of sulphuret of iron, which are decomposed for thirty or forty feet in depth, but below the water level, the sulphuret becomes visible. Copper is never found in this species of auriferous deposit. It is absent again in the thin auriferous belts, which rarely exceed six inches in width, in slates of a similar character. These are false veins, as they are destitute of walls. So copper is absent in some of the veins of auriferous iron pyrites. But a very large proportion of the veins which carry gold carry copper also; and some of them have become the best copper mines in North Carolina. The upper part, or back, as this part is sometimes called, is simply a decomposed iron pyrites; but when the lode is penetrated thirty or forty feet, the triple compound of sulphur, copper and iron, comes in, and increases in quantity with the descent, or in other words, it becomes a copper lode. A few years ago a change of this kind was dreaded, as it was invariably deemed necessary to abandon them, for no other reason than that it cost too much to separate the gold from alloy, which would be found with the copper. At this time many of these abandoned gold mines are regarded

as the best and most valuable mines for copper. As lodes or veins they furnish nothing new as to structure, or add to those facts which are interesting in the eyes of a geologist. The gold is sacrificed, or at least no successful attempts have been made to save it; although it has been proposed, first to separate it by the usual mineral process, and afterwards smelt the remaining cupreous material.

While there is a general similarity in the structure of the veinstone, and arrangement of the materials constituting the lode, there are a few peculiarities belonging to individual veins, which are worthy of a passing notice. The McCulloch vein, in Guilford county, N. C., for example, is remarkable for its width, and the extent or depth to which the decomposition of the ore extends, which can not be less than one hundred feet. The vein expands to seven and eight feet in width, and contains, notwithstanding this great expanse, very rich ore; and the proprietors did not work ore which yielded less than one dollar per bushel. It is a magnificent vein.

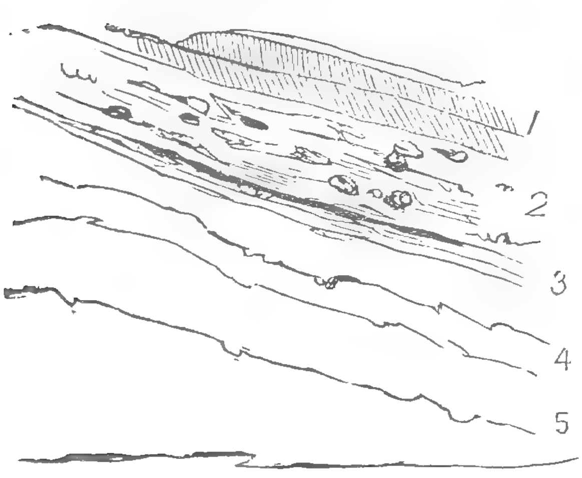
The Gold Hill veins have also been very successfully worked. Their greatest width is seven and eight feet, and the principal vein has never been less than two feet. This vein has been worked to the depth of five hundred feet. It is an auriferous quartz and copper pyrites, in a green fissile slate. It often yields five and six dollars per bushel of ore. The Reed mine, Cabarras county, contains but little pyrites, but it is remarkable for the large masses of gold it has furnished; one of which weighed twenty-eight pounds, another sixteen, and another nine, and so on in respectable lumps, which have been very numerous; and another of sixty pounds: though it requires to be more fully authenticated, still the evidence of the fact is by no means slender.

The Fentriss copper mine in Guilford county, North Carolina, has furnished a large amount of ore. This vein is forked, or consists of a flat vein, rising at an angle of ten degrees towards the surface. Its veinstone is a coarse quartz, carrying large lumps of sulphuret of copper and iron on its inferior side.

When it unites with the vertical vein it swells out to a width of seven or eight feet. It carries also a quantity of iron pyrites which is silver white. It has not been analyzed, but probably contains arsenic and cobalt. Among the remarkable veins of the south, those of Ducktown, Polk county, in Tennessee, have probably excited the most attention. The rock is a talcose slate, interlaminated with hard layers of gneiss and hornblende, and highly inclined. There is nothing in the general appearance of the country which indicates a mining region, and accident alone brought to light the remarkable repositories of copper ore. The ores of this district are in some respects unlike those of North Carolina: they are arsenical, and probably to the presence of a third metal the peculiar condition of the copper ore is due.

A section of the Congdon vein at this place, gives all the information we desire respecting this structure.

Fig. 41.



1 Talc Slate, 2 Gossan, 3 Bell metal, 4 Black oxide of Copper, 5 Mundic.

The section is vertical and longitudinal for the purpose of showing the slope or pitch of the materials of the lode, for it has a slope in addition to its dip. The following exhibits the order of arrangement: 1, talcose slate; 2, Gossan, or hydrous peroxide of iron; 3, bell metal ore; 4, black oxide of copper; 5, masses indicative of the commencement of the yellow sulphuret or mundic. The Gossan was seventy feet thick in the direction of the shaft sunk upon a hill. It is destitute of copper in the upper part of the mass, but it is present in the lower. The bell-metal ore is only from twelve to sixteen inches thick, and the thickness of the black oxide is variable in consequence of resting upon an uneven floor, but exceeded three feet. The width of this vein at the surface is five feet, with its

walls very well defined. At the depth of thirty-five or forty feet, its extreme width is forty feet. No one can inspect this lode and be uninterested in the chemical changes that have taken place since the fissure was filled with metal. The first change which perhaps would be noticed, is the perfect destruction of the original lode. Its gangue, which is quartz, is dispersed through the mass of black oxide and gossan in part. The true, original walls are broken down, and the copper is extended laterally into oven-shaped cavities, in the soft adjacent slate. The smaller oven-shaped expansions extend into the rock six or seven feet, the larger still farther. The smaller are three or four feet high, and as many wide, and as they are occupied entirely with the black oxide of copper and its gangue, the contents only require to be shoveled and screened, in order to be prepared for market. Three hundred tons of this ore were taken out from this vein in one month. The chamber, after the removal of the ore, presents an irregular shape. Its roof is more uniform from the existence of the layer of bell-metal ore.

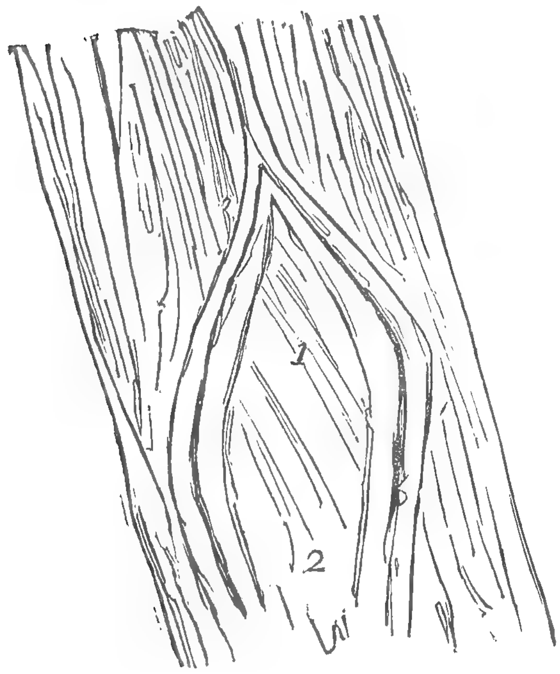
This vein presents its most remarkable feature only when we contemplate it in its original condition; when the iron, copper, and arsenic were in combination with each other, and arranged in the usual order. Now we find the copper in the form of a black oxide, occupying the lowest place in the lode. The iron forms a mass seventy feet thick overlying all the rest. The more volatile elements, sulphur and arsenic, have disappeared. The change is undoubtedly one which should be referred to molecular forces, representing in its effects the formation of nodules, septaria, and sometimes entire strata.

Ducktown can boast of five veins, rich as the Congdon, and similar in structure. Here is, therefore, a peculiar mineral district, rich beyond any which had been explored, and yet there is nothing upon the surface which would lead a geologist or miner to suspect the value and magnitude of the mines beneath it. It is true that on the surface there are mounds of gossan, or the hydrous peroxide of iron; yet copper is never

found upon the surface. The slates of Tennessee, Virginia, and North Carolina abound in this species of iron ore; but so far as discoveries have yet been made, the mounds of oxide of iron do not overlay copper, except at Ducktown.

A vein three miles south from the Congdon mine, and just within the limits of Georgia, exhibits the general original form of the lodes in the vicinity of Ducktown (fig. 42). This vein was discovered by following the indications furnished by the gossan. Upon the surface this substance was observed to be rather common at the locality referred to, and selecting a place which represented the center of dispersion, a shaft was sunk almost at random. When the earth was removed from the rock a narrow crevice was observed, which contained the gossan; and on following it down twenty-five feet, the crevice expanded into a large pipe vein of the form presented in the figure. This peculiar lode was struck five feet higher on the north side of the shaft than upon the south. This pipe vein penetrates the rock obliquely. The black oxide of copper and gossan occupy the same relative position as at the Congdon vein. The Congdon mine was originally a larger pattern of the same kind of vein as the Georgia mine. At the deepest part of the shaft this is five feet wide, and a ton of black oxide was taken out of it.

Fig. 42.



The Georgia mine is noticed for the purpose of illustrating the peculiar form of the pipe vein, which seems to constitute an interesting feature in the Ducktown mining district.

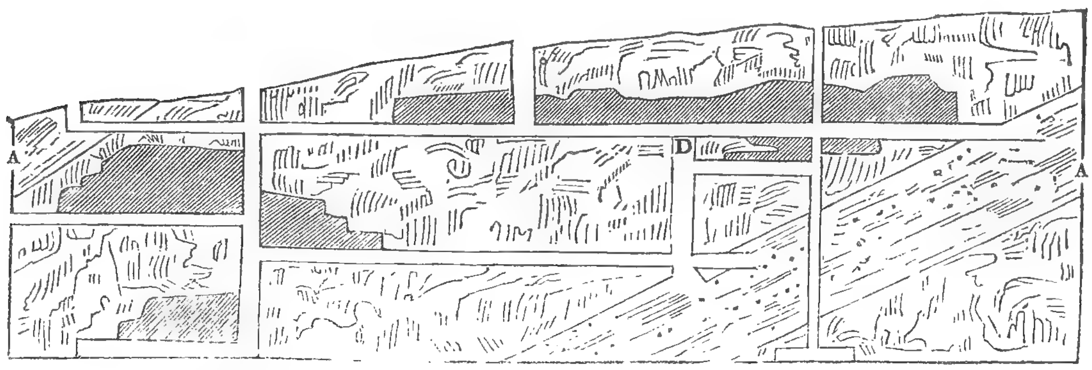
COPPER MINES OF LAKE SUPERIOR.

§ 103. The occurrence of native copper, in sufficient abundance to make it an object of commercial value, is one of the most recent of geological discoveries. The fact is another illustration of a remark, that each mineral district contains a certain type of mineral character peculiar to itself. That type does not seem to be entirely dependent upon the surface geology; for that of Polk county, Tennessee, is not ostensibly different from North Carolina. Many other illustrations of the fact might be given.

The geological position of the copper has been determined by the late Dr. Houghton and Dr. Jackson, and confirmed by other American geologists. They have shown that the native copper lies in veins in the trap rock, and that this rock forms alternations with the potsdam sandstone; and save the exception, the exclusive metallic condition of the copper, its repositories do not differ from those where it is found in other states, as that of the sulphuret or the gray copper ore.

As a general illustration of the copper lodes of lake Superior, I have copied the annexed diagram from Foster and Whitney's Governmental Report (fig. 43). In this diagram the shaded

Fig. 43.



A A layers of sandstone, D mass of trap containing the copper.

part shows where the copper has been removed by means of the vertical shafts and horizontal galleries. It will be observed

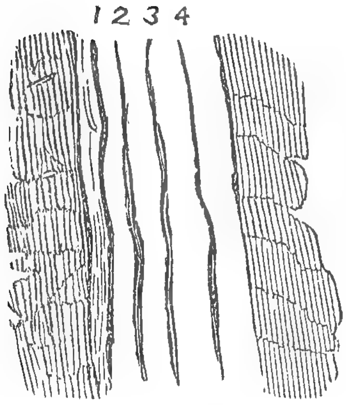
that two of the horizontal galleries penetrate the borders of the sandstone, but are soon discontinued. It is proved by many observations, that an ore or metal in passing from one rock to another is greatly diminished in quantity, or the contrary. In the case before us, the copper, when it passes into the sandstone, becomes a mere thread or string; and though the fissure may exist, or may have been formed, the metal it contains bears no comparison in quantity to that in the trap rock. The fissure of the sandstone, if it equals in width that of the trap, will be filled mostly with veinstone. It can not escape the reader's notice, that this fact—the change which a vein undergoes in passing from one rock to another—is one of the most interesting, as well as important, in all mining operations where two rocks bear the same relations as those of the trap and sandstone of lake Superior.

The traps, however, are not equally productive in metal; and there appears to be as much difference in the three kinds of trap, the soft amygdaloids, hard granular trap, and the greenstone, as between the most productive trap and sandstone. The soft amygdaloids contain copper lodes, but they are thin, branching and scattered; while in the hard greenstone the veins are contracted and pinched out. In the fine granular subcrystalline trap the veins reach their maximum of excellence.

The gangue of the copper lodes is in keeping with the rock which contains them. The zeolites, prehnite, laumonite, &c., are minerals of trap rock; so in their geological position they become the veinstone of the copper, and other metals of the rock. Calcspar is also a veinstone, but it is also an associate of zeolite. It appears from this fact that the veinstone is derived from the rock containing the vein.

The veins of native copper vary in width. I may cite, as an illustration of the fact, the well known Cliff mine, situated on Keewaunee point, three miles from the lake shore. The outcrop of the vein is in a cliff of greenstone. It is only two inches wide in prehnite as its gangue, but an exposure on the

Fig. 44.



Parallel masses of copper and rock, forming the vein.

line of dip disclosed the fact that its width increased. With this encouragement, the vein at the base of the cliff was exposed. At this point the vein had increased to two feet in width. This encouragement led to the further exploration of the mine, which soon afterwards led to the discovery of immense masses of native copper, some of which weighed fifty or sixty tons. From the first discovery of these masses, the mining enterprise assumed a better aspect. The progress of discovery has kept pace with the labor and expenditure of capital; and now the mines of lake Superior take rank with the most productive mines of the world. The shipments of copper from Cliff mine have amounted to 1800 tons per annum, containing from sixty-five to seventy per cent of pure copper.

DISSEMINATED NATIVE COPPER IN HORNBLENDE.

§ 104. In the southern counties in Virginia, native copper has been discovered which occurs in small pieces in hornblende, with epidote in combination. It shows no tendency to arrange itself in veins, but is distributed irregularly in masses from the size of a pigeon shot to an almond. This discovery of copper was made in Carrol county, Virginia, and it has been found over a region thirty miles long, the breadth of which is undetermined, but not over, it is supposed, ten miles.

It appears that the discovery, up to this time, is interesting to the geologist, rather than useful to the miner or capitalist. Its origin is no doubt coeval with that of the rock. The cabinet specimens which I have seen, bear a trappean aspect.

VITREOUS OR GRAY COPPER ORE.

§ 105. In North Carolina, Chatham county, several veins of copper have been discovered, having at the outcrop of the vein and for fifteen or twenty feet more, gray copper; but it gives place to the yellow sulphuret sooner or later. There is nothing peculiar in the structure of the veins which carry gray copper. It is worthy of remark that it is massive, and that it is probably an altered yellow sulphuret.

The gray copper of Bristol, Conn., is associated with the yellow sulphuret and sulphuret of iron. It is remarkable for its fine crystals of gray copper.

The red sandstone of Connecticut and New Jersey contains the carbonates, sulphurets, red oxide and blue sulphuret of copper. The locality at Simsbury, Conn., was known in the time of the revolution. Those of New Jersey appear, many of them, to be exhausted. Mining operations have been prosecuted at Somerville, Woodbridge and Farmington. As the efforts to obtain good veins of good mines of copper have signally failed, it is a matter of interest to determine the causes of these failures. Prof. Rodgers, who has investigated the question very carefully, came to the conclusion that veins do not exist—that the copper occurs in proximity to the trap, and without veinstone or mixture of other metalliferous matter, but in ramifying strings or bunches, which are more or less blended with the adjacent rock. At the Schuyler mine, the sulphuret and carbonate occur in a sandstone twenty or thirty feet thick, in which it is imbedded and forms a band which traverses the layer in a series of offsets or steps, and which has been pursued to the depth of 212 feet below the surface. The phenomena which bear upon the origin of the copper ore of the sandstone, seem to favor the view that it was sublimed through shrinkage cracks, or imperfectly formed fissures, and which also penetrated more or less between the layers and into the porous substance of the sandstone.

In the north-western part of New York, the sulphuret of copper is found connected with the pyrocrystalline limestone, in strings and bunches. Its origin in this instance may also be attributed to a like cause.

THE LEAD BEARING ROCKS OF THE UNITED STATES.

§ 106. The only ore of lead which is found in sufficient quantities to pay a profit to the miner, is the sulphuret of lead or galena. It is found in rocks of several epochs. The Pyrocrystalline, the Taconic, Silurian and carboniferous, are each of them lead bearing. In the Alleghanies and other primary ranges, it is found in veins. The gneiss of this great range is generally the repository of it, as at Rossie, St. Lawrence county. It occurs in veins also in all the systems I have named. At Ancram in Dutchess county, it is in the Taconic system; near Spraker's, on the Mohawk, and at Martinsburgh, it is in the Lower Silurian. At Wisconsin and Iowa, Upper Silurian. In Derbyshire, England, it is in the Carboniferous system.

The Rossie lead mine has been worked to a greater depth than any other lead mine in the country, and hence may be referred to for the purpose of illustrating the general facts which pertain to the repositories of lead in gneiss, as well as the other rocks which belong to the same class. I have already had occasion to refer to the lead vein of Rossie, the structure of which is exhibited in the figure. The vein is exposed at this place in consequence of a shift in the gneiss by which it has been elevated thirty-five or forty feet above a low swampy country, which bounds the outcrop of the rock on its eastern side. The peculiarities and characteristics of this vein as well as other veins, are exhibited in the cut, Figure 25.

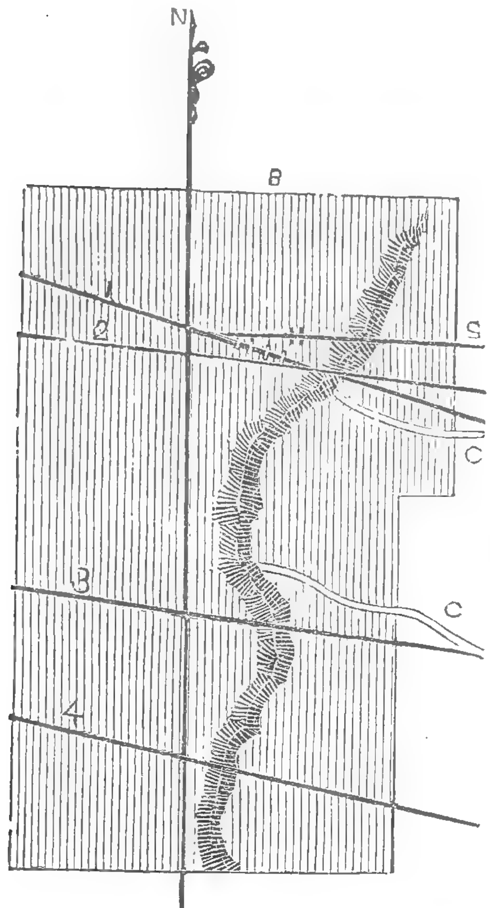
The middle dark broad line represents the position of the galena, imbedded in a calc spar on each side, and which fills the fissure. When the outcrop of the vein was exposed, the white gangue of spar, and the brilliant seam of lead in the

middle, formed a fine and beautiful contrast with the darker and sharply defined wall of gneiss which inclosed it.

The wall of rock which rises out of the low, flat and swampy ground, seems to terminate here, and to limit the extent of the vein in this direction, as no rock appears for one-fourth of a mile. This wide interval and absence of rock is due to diluvial action, at least in part, its upper part having been removed; but the vein and rock continues in the direction indicated by the strike of the vein, beneath the low grounds; and the workings of the vein may be carried on beneath these grounds, which are frequently covered with water, which sets back from Indian river, with which they communicate.

I have had occasion to observe more than once, that it is a rare circumstance that a vein fissure is produced without being accompanied with others also. This fact I propose to illustrate again by the accompanying ground plan of veins which have been discovered at Rossie.

Fig. 45.



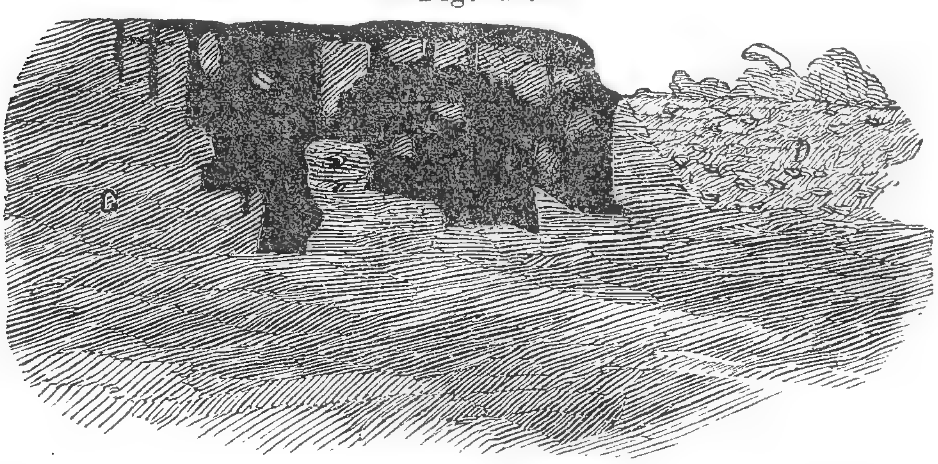
1 Union vein, 2 Vic. vein, 3 Coal Hill vein, 4 Indian river vein.

Fig. 45 exhibits four lead veins which constitute this mineral district. Thus, 1 shows the bearing of the Union vein, which is S. 73° E. It sends off a branch S. 88° E. 2, the Victoria vein, whose bearing is S. 84° E., with its diverging branch; 3, the Coal Hill vein, bearing S. 82° E. This is the vein already referred to in Fig. 25. 4, Indian river vein, bearing S. 75° 45′ E. The heavy transverse shaded band shows the boundary between the high and low grounds already spoken of. Two of the veins have been extensively worked. The great Coal Hill vein was first discovered, and has been explored to the depth of 200 feet, and has furnished $241·000 worth

of metal. This mine, which was opened in 1836, although it presented a fair prospect of yielding large dividends to the owners, yet was abandoned after three or four years' trial. This arose from great extravagance and unskillfulness in mining. The work was prosecuted by opening the vein for a great distance along its outcrop, which exposed it to inundation from surface water.

To exhibit the plan pursued in opening and working this mine, I have copied the following diagram, Fig. 46, by which it will be seen by the darkly shaded parts of the figure how much galena has been taken out of the mine.

Fig. 46.



It will be observed that this shaded part extends the whole distance along the outcrop. Where there should have been at most two shafts, there is a trench extending the length of the vein as far as worked, some twenty or thirty feet deep, the effect of which is to convert what should have been closed into an open way for the ingress of water, which, in some cases, would totally ruin a mine.

The most important lead-bearing rocks of this country belong to the western states, Illinois, Missouri, Iowa and Wisconsin. The lead of these states belongs mostly to one rock, the Cliff limestone of the western geologists, the lower part of which is equivalent to the Niagara limestone of New York. Lead is also found in the calciferous sandstone, the lowest limestone of the Silurian system. In New York, this lower

limestone is not destitute of lead and zinc; it is in a sufficient quantity to keep up the analogy between the beds of rock of the same age at distant points. These limestones are both magnesian, though the magnesia is variable in quantity in the different layers.

The composition of the lead-bearing rock of Wisconsin was found to be as follows:

Carbonate of Lime,	47·40
" Magnesia,	40·70
Oxide of Iron,	2·40
Silex,	7·10
Water,	2·00
Loss,	40
	100·00*

The texture of the rock differs in different places; in some it is friable like a sandstone; in others, hard and durable. It is also cherty or traversed by bands of compact quartz resembling flint.

This rock is generally favorable both for the reception and retention of the metals. It has been fissured extensively, and these fissures had remained open until they received the lead or copper or other metals which we find in them.

A fresh fracture of the rock exhibits a sub-crystalline aspect, a flat conchoidal surface, a granular texture, and a light yellowish or drab color. When weathered it is brownish or reddish yellow. Specific gravity 2·65 to 2·70.

Owen divides the Cliff limestone into, 1, upper or shell beds, consisting of a white or light colored limestone, destitute of magnesia, fossils calcareous; 2, middle or coralline beds, which are cherty and magnesian, and of a yellowish color, fossils silicious; 3, lower or lead-bearing beds, color yellowish and composition magnesian. The rock presents cliffs when it appears at the outcrop, which are more or less fissured and separated

* D. D. Owen's Rep. of Geol. Expl of Iowa, Wisconsin and Illinois, 1836, p. 24.

into columns. Its stratification is obscure and its vertical fissures numerous, and which are sometimes prolonged or extended horizontally.

Wisconsin, and the states which are lead-bearing, have been subjected both to the denuding action of a rush of waters, and to a slower disintegration of rocks by the common atmospheric agencies. These external influences have wrought many alterations in the rock, and have also changed the position and association of the metal which the rock contains. Originally, the galena was injected into its fissures, which it undoubtedly filled, and which it continues to occupy in part; but in consequence of the disintegrations which the rock has suffered, all the upper parts of the veins seem to have been broken down, and the lead has become commingled with a stiff, reddish clay. The galena is therefore found in veins and in beds.

LIMITS OF THE VEINS OF THE LEAD-BEARING STRATA.

§ 107. The lead is not confined wholly to the lower cliff limestone. To a limited extent, it reaches the blue limestone beneath, though this rock is not by any means so rich and productive. The lead, therefore, for all useful purposes, so far as is known, is confined to the Niagara limestone, and to the overlying debris which contains the products of the broken down veins.

The fissures vary in thickness from a few lines to fifty feet, but Mr. Owen remarks that the common width of the fissures filled with solid metal is about four inches, and rarely exceeds twelve inches. One instance is given in which the galena of a fissure was six or eight feet thick in the center, and extended thirty-five feet; it tapered to a point at each extremity. The foregoing statement leads to another still more remarkable in the annals of lead mining. Thus, fissures sometimes expand into large caverns, the walls of which are lined with galena, while this is overlaid or incrusted with spar, stalactites, etc. The galena which lines these large chambers is sometimes

twelve inches thick. The enlargement of fissures subsequent to the beginning of the metallic accumulation has been mentioned already, but the peculiarity in the cases referred to, is no doubt due to the nature and composition of the rock.

The direction of the lead veins is east and west, or rather south of east. When north and south they are less productive, though exceptions to this statement do occur. The peculiar fissured condition of the limestone has produced a great irregularity in the dip of the veins. Instead of dipping regularly, and at a constant angle, the dip takes the form of several successive offsets. Thus, for a given stratum, the angle of dip may be 45°, but in passing to the south it may be more oblique or become horizontal, by following the bedding plane between two strata, pursuing a route where the difficulties and distractions are readily overcome. When, however, it has taken a horizontal direction, it may pass to the vertical. There is therefore great irregularity in the dip or lead of the vein. The fissures of the Cliff limestone usually stop short of the superincumbent limestone, and hence are capped over by the upper mass.

POSITION OF THE ORE, AND THE LEAST THICKNESS OF VEIN WHICH CAN BE WORKED WITH PROFIT.

§ 108. The broken down veins are concealed in reddish clay, ferruginous sand, masses of rock, etc. The lead is then obtained from these deposits by digging.

The position of the ore in the vein is often changed, and it has been in process of time detached from its walls, and is obtained in pieces varying in size from a pea to those of a thousand pounds weight.

The width of vein required for working may be profitable if it does not exceed half an inch, provided the ground is not very hard. It is evident the profits of working a vein depend on the character of the walls, gangue, etc.

INDICATIONS OF THE PRESENCE OF A VEIN BENEATH.

§ 109. It has been observed that where a *sink hole* occurs there is a probability of finding lead. So, when a series of them can be traced upon the surface in an east and west direction, there is probably a fissure in connection with them, which will prove to be lead-bearing. Depressions, miniature ravines, the presence of barytes in the debris, or calc spar, become indications of the existence of a vein fissure in the neighborhood. In *prospecting* for lead, the miner looks for the above indications. Mineral gravel, the existence of the Coscinopora Sulcata, Goldf., is regarded also by Mr. Owen as indicative of the presence of a vein in the vicinity.

The galena is associated with blende, calamine and sulphuret of copper. Instances occur when calamine displaces the galena and becomes the principal mineral of the lode.

EXTENT OF THE LEAD-BEARING ROCKS OF THE WEST.

§ 110. The lead region comprehends eighty townships, or two thousand eight hundred and eighty square miles, and is about one-third larger than the state of Delaware. The length of the lead region, from east to west, is eighty-seven miles, and its greatest width, from north to south, fifty-four miles. The produce of the mines of the upper Mississippi, exceeds 50,000,000 of tons annually, which is probably less than one-half the quantity this region is capable of producing under increased facilities and a better system of mining.

LEAD AND ZINC OF NEW YORK, MASSACHUSETTS AND CONNECTICUT.

§ 111. The lead mine of South Hampton, Massachusetts, was opened as long ago as 1810. Its value has never been determined. The vein together with the gangue is seven or eight feet wide at the surface, is vertical, and is included in granite.

This mine is now being opened again, after having been abandoned for thirty years, with some prospect of success.

Galena occurs in more than twenty places in the old county of Hampshire, and in veins which seem to be well defined, but the low price of lead has operated to prevent their exploration. They all belong to the pyrocrystalline rocks, and the ore is associated with pyritous copper, sulph. of iron and blende, together with the rarer minerals, sulphate, carbonate and molybdate of lead. The gangue is barytes and crystallized quartz. The probability is, this region is an extensive lead district which will one day become important.

Another lead region has been explored rather extensively in Ulster, Sullivan county, New York. These mines are known as the Ellenville, Ulster and Shawangunk mines. The latter is near Wurtzborough, in Sullivan county. The first occupies a transverse break in the Shawangunk grit; its direction is S. 60° E. The mineral matter filling the fissure consists of galena, iron pyrites, blende and copper pyrites. Galena and blende predominate. The gangue is quartz.

The Ulster mine is near Redbridge, upon a line of fault, according to Prof. Mather, lying between the grit and slate, the Hudson river slates having been upheaved.

The Shawangunk mine occupies a fissure in the grit of that name; a rock which is equivalent to the Oneida conglomerate. The fissure is from two to five feet wide, and was opened between the strata, but it shifts its dip in a manner resembling somewhat the mines of Wisconsin. It carries galena, blende, iron and copper pyrites, intermingled with crystalline quartz which forms the veinstone. Very large masses of galena have been raised from this mine, one of which weighed 1400 lbs. Neither of these mines have proved profitable, though they are not to be regarded by any means as valueless. The galena of the Shawangunk mine is argentiferous.

It will be observed on reviewing the principal points respecting the geological position of galena, that we find it associated first with the pyrocrystalline rocks, and second with the paleo-

zoic rocks. In the latter it ranges from the calciferous sandstone to the Niagara; these extremes together with the included rocks contain veins of galena. In Europe, especially in England, it extends upwards into the carboniferous limestone. So far as observations have been made, this ore does not occur in veins in the Messozoic series.

The foregoing facts sustain the doctrine which many distinguished geologists have inculcated, that metalliferous veins are productive and important the nearer they are to the igneous rocks, and those districts which are rich in metals, are traversed and disturbed by them. The Wisconsin lead district, however, is much less dyked and disturbed than any other one in this country which is equally rich and productive in metals.

ON THE EXPENSES ATTENDING MINING OPERATIONS.

§ 112. It is scarcely necessary to observe that the expense of working a mine must depend upon a variety of circumstances, and that the estimate of those expenses which will probably accrue in the working of any given mine, will not be applicable to any other though the actual amount of metal may be the same in each.

In some cases a work may be prosecuted successfully without the aid of gunpowder, in others the hardness of rock may become excessive at certain depths, and trap dykes may cut off a lode, and hence heavy expenses will be incurred, in recovering it. Variability in the hardness of rocks is one of the principal causes of the difference of expense in working mines which belong to the same rock or formation.

Mining operations embrace three kinds of work—shafting, tunneling and stoping. Shafts are right-angular cuts into the soil and rock, in which respect they differ from wells. They may be perpendicular or inclined. They are necessarily perpendicular if the lode is vertical; they may be inclined and sink upon an inclined lode to great advantage by employing a proper apparatus for elevating the mineral. But they are more

frequently vertical, and sunk at a distance from the outcrop of the vein so as to intersect it at any given depth which may be desirable. To do this it is necessary to ascertain in what direction and how much the vein dips, or in other words, how many feet the vein makes on the dip side in any given number of vertical feet. Thus a vein may make to the west seven feet horizontally in seventeen vertical feet. It is easy from these facts to calculate how far west from the outcrop the shaft must be sunk to intersect the vein at one hundred or two hundred feet; and so of any other ratio which the vertical plane may bear to the inclined one. It is to be borne in mind that a very flat vein, as has been already observed, will become steeper as it descends. In very flat veins, therefore, calculations of this kind can not be relied upon until the vein has reached its maximum dip.

Tunnels or drifts are horizontal cuts into the earth or rocks. They may be designed both for conveying outwards the mineral and for drainage. In that case they are made from the outside, or begin on a slope and are worked inwards, or they may proceed from a shaft to a lode which lies upon one side of it.

Stoping is a term applied to that kind of work by which the vein, or its metal, is removed from its bed. The most economical way is to stope from beneath upwards. The dead rock is readily disposed of, and placed so as to save the expense of raising it to the surface, and at the same time aid in supporting the walls. The arrangements for stoping should be such that several gangs of miners may be employed in taking down the vein at different levels at the same time. In this case they will be arranged generally in a series of steps, one above another. The cost of a shaft seven feet by five, and sixty feet deep will not be less than two dollars and a half per foot. If sunk to one hundred feet, it will not be less than four dollars per foot. A windlass will answer for the purpose of raising rock and earth for the first sixty feet, but a whimsey, or whim, is more economical below that depth. The apparatus for raising the rock and water, however, must depend very much upon cir-

cumstances. If it is a trial shaft merely, and the vein is of a doubtful character, it will not be prudent to incur the expense of a whimsey until after the vein has been proved to a certain extent.

Other expenses are incurred in mining operations before the mineral is ready for smelting, besides those which attend the shafting, tunneling and stoping. Almost all ores require roasting in order to fit them for stamping. There are, therefore, three operations, at least, to which the ore must be subjected to fit it for smelting, viz: assorting, roasting and stamping or crushing. Passing by the expense of assorting, as this must be the most variable of the three, and can not be calculated before trial, I proceed to state the expense of roasting and crushing a given amount of iron ore. The roasting is performed in kilns of a simple construction.

One kiln, containing 107 tons of ore, will cost:

1. For mining, fifty cents per ton,	$53·50
2. Five cords of wood, two dollars per cord,	10·00
3. Teaming one hundred rods,	11·50
4. Labor for filling the kiln,	16·00
	$91·00

In the case of iron, there is usually the expense of separating the rock from the ore, which is effected either by magnets or by washing. If the first method is adopted, the expense will amount to

1. 6 men, $2\frac{3}{4}$ days in crushing, one dollar per day,			16·50
2. 1 engineer, $2\frac{3}{4}$ days, at	$2·00	per day,	
3. 1 assistant, 1 "	1·50	"	
4. 1 machinist,	2·50	"	
5. 1 man, "	1·25	"	
6. 3 men, "	1·00	"	
7. 1 boy, "	50	"	
			40·42
8. 10 cords of wood for engine,			20·00
Total cost,*			$167·92

* Sandford mine, Essex county, N. Y., Lot 21.

There will also be a loss of ten tons in shrinkage, which will leave only ninety-seven tons of ore after it has passed through the several operations. As separated ore is now selling, this will be worth $253 00

Phosphate of lime saved, worth 125 00

The allowance for loss in separating by water is about twelve tons per one hundred.

VALUE OF THE MINING PROPERTY IN CERTAIN STATES OF THE UNION.

§ 113. The country is not wanting in a class of persons who decry mining enterprises and pronounce all attempts for developing its mineral wealth, schemes more fraught with expectation than with reasonable prospects of fruition. This class, though wealthy, never invest their means or their money in mines.

There is another class who may be equally unbelieving in the real value of mineral property, yet are ready to plunge into any scheme or project in which there is enough to make a bubble, something which may be inflated into consequence. This class of men have little to lose, and being reckless in representation, are ready to avail themselves of such arts as are necessary to advance their unrighteous schemes.

There is also a third class, who look at matters in a different light. They are satisfied that there are valuable mines, and moreover, they look at the world as progressing in the arts, and requiring every day for its progress, the wealth which is concealed, except to the eye of science, in the bowels of the earth. They see that for years to come, the increased wealth of the nation is to be drawn from this great storehouse. They are disposed to invest their money in this kind of property, and to be content with the fair gains of the business. They are aware that it is not without its risks, but to diminish them resort to all the means which may be necessary, in each particular case, to secure a successful result.

The course pursued by the second class has been so notorious, as to give character to mining enterprises, and to invest them with a suspicious appearance.

I have not space, however, to follow up this subject. My principal object now, is to state, very briefly, the value of some kinds of the mining property of our country, for the purpose of placing the subject in a prominent light, and thereby show that it is for its interest to foster and encourage all mineral enterprises which are undertaken in a proper spirit.

The time is not far distant when mining will form one of the great industrial pursuits of the country. Every blow of the pick, and every gunpowder blast, will add their farthings to the common wealth of the nation, for every pound of copper or iron is a real addition to its resources.

1. Northern New York. The net proceeds per annum, which may be realized from the ores of iron in northern New York, will pay the interest, at seven per cent, on $3,000,000.

The mines at Adirondack have just been sold for $500,000, a sum much below their real value. The Sandford ore bed in Essex county, can not be estimated at much less than $500,000. At this mine, from two pits alone, 21 and 23, 200 tons of ore per day have been raised at a cost not exceeding fifty cents per ton; and which, when crushed and separated, yields from five to fifteen tons of phosphate of lime per one hundred tons of ore, which is worth on the ground twenty dollars per ton, and twenty-five to thirty dollars in New York.

There remain the Clintonville and the Saranac iron districts, together with inexhaustible quantities of the specular ore in Jefferson and St. Lawrence counties, and the magnetic ores of the Highlands.

2. Pennsylvania furnishes an amount of iron which may be estimated at $5,000,000, annually.

3. Missouri, from the Pilot and Iron mountains is capable of furnishing as much iron as any part of the world. Situated in the great valley of the Mississippi, its value can scarcely be overrated.

4. The iron mountains of lake Superior are equally as rich as northern New York. There are some, perhaps, who may regard this comparison as unjust to lake Superior; but it must not be forgotten that one mine, the Sandford Lake mine, is between six and seven hundred feet thick. A square yard of ore weighs four tons.

5. Maryland, Virginia and North Carolina possess inexhaustible supplies of iron ore, which are mostly the hydrous peroxides of iron. The hematites of Vermont, eastern New York, are very extensive.

6. The brown ores of iron in the south-western counties of North Carolina, and in eastern Tennessee, are immense.

A mineral so important as iron should be widely distributed, and it appears that in the United States, every important section is supplied with it. The largest section or formations which are destitute of the ores of iron and of the metals, are the Cretaceous and Tertiary, which skirt the Atlantic coast and which form our great basins and valleys. So also, the Silurian and Devonian systems are in a great measure destitute of iron ores, with the exception of the argillaceous and oolitic ores of iron of the Clinton group.

7. I have already spoken of the value of the lead ores of Wisconsin, Missouri and Iowa. The highest estimate which I have noticed of the probable productive capacities of the lead region, is from one hundred to one hundred and fifty millions of pounds annually, having already reached that of fifty millions under unfavorable circumstances.

8. The production of copper is in its infancy. It is too early to attempt to determine the value of its mines, and yet the lake Superior copper district has already produced two thousand tons in a single year. The value of the copper which has been produced equals, at twenty-five cents per pound, $2,700,000. The copper region which ranks next in value is in North Carolina. It has been referred to. The ore is the yellow sulphuret; the country is far better adapted to mining than that of lake Superior. Indeed, it is of all others the best, whether we

consider its climate, its means of sustaining a mining population at a cheap rate, or the production of timber for shafting, tunneling, fuel etc. We do not yet know the real extent and value of its copper ores, but we have not the least doubt of the ultimate success of its copper mines.

It is not to be expected, however, that one-quarter of the veins which are now being tested will prove to be mines. Even if one in ten turn out well, North Carolina will become one of the richest mining districts in the Union.

The resources in copper in Tennessee are also remarkable, and particularly so as several mines became productive from their first trials. I allude to those of Ducktown.

9. Although gold has been obtained in considerable quantities for half a century, still the mines and deposits have not been worked in a systematic manner. Gold mining operations have been conducted in the loosest manner. Present and immediate gains have been sought for, and hence no permanent works have been erected, except in a very few instances. Within the last two years, more system and more capital have been employed, and a better and more consistent view is now taken of gold mining, and the prospect is becoming daily more favorable to the enterprise. North Carolina is the center of the gold region, and will rank in value next to California. There are no accurate returns for the amount of gold North Carolina has furnished. Of the gold of California, the estimated production is less than the actual. The Hon. T. Butler King estimated it for 1848-9, at $40,000,000.

10. Our plaster, salt, marble, granite and freestone, form other large items of mineral wealth with which the United States abound. In the list of mineral property, mineral springs should not be forgotten. They administer to the health of the people.

11. The only mines of quicksilver which are now known in the United States, are situated in Santa Clara, twelve miles from San José, in California. It is found in bunches in ferruginous clay, forming in part a hill 1360 feet above tide. It is

associated with broken down magnesian rocks. The deposit is large, but no accurate returns of the yield of quicksilver have been published. The mine is being worked in a systematic manner.

We have no mines of tin, properly speaking.

I have said nothing of coal. It is almost impossible to measure or weigh in calculation its amount. But President Hitchcock observes truly, that the whole amount in solid measure, of the coal in the United States, equals at least 3,500,000 square miles.

When it is considered that our country is destined to support its hundreds of millions of souls, that its fleets, its mines, its manufactures, its locomotives and the domestic firesides must depend upon its mineral fuel, and when we also estimate the vastness of our resources in the mineral kingdom, we can not but see that everything necessary for prosperity has been provided with the most liberal hand, and on the most gigantic scale; and has moreover been so distributed as to accommodate the many and the most distant parts of the Union. There can be no centralization of products and resources, so as to confer a preponderating influence on a few favored sections of the Union, in the south or in the north. But enterprise and industry may create any where a prosperous community by availing itself of those natural mineral and manufacturing resources which are provided throughout the land. Where these do not exist, agriculture comes in to supply the necessary elements of prosperity. Nature had no sectional favors to dispense when she grew the coal plant for nine hundred miles from north to south, and more than a thousand miles from east to west, extending over an area of a million of square miles, and at the same time distributed her iron and other metals still more widely; to say nothing of the lands and mineral productions upon the Pacific slope.

Although I have not pretended to present a statistical account of our mineral resources, and what is recorded in the foregoing paragraphs is exceedingly meagre and unsatisfactory, still

enough has been said to prove that our mining interests are to become one of the great sources of wealth, and that the real additions to the wealth of the nation is hereafter to be largely derived from its mines and quarries.

STATICS AND DYNAMICS OF GEOLOGY.—CONCLUSION.

§ 114. Geologists have often employed the phrase, "*The Dynamics of Geology*," which, if it is appropriate, has its counter phrase, "*The Statics of Geology*." The first comprehends all that relates to the processes which are productive of change; the latter, all that relates to the rocks and formations as they are, without regard to the cause or causes which have been influential in the development of their present condition.

Statical geology stands first in the order of time; it is descriptive in its objects and ends, and contains a record of the phenomena which they exhibit.

When statical geology was wholly neglected, dynamical geology was ridiculous and absurd. Indeed, it is impossible to construct the dynamics of the science, without first perfecting the statics. The dynamics of our principal mountain ranges will be better understood when their statics have been more thoroughly studied. The dynamics of our great system of lakes seem to point to diluvial action as a cause, but we require more facts before that theory can be established. If our dynamics do not grow out of, or legitimately follow from our statics, we are likely to beget error rather than truth. If, on the contrary, the dynamics grow out of our statics, truth is begotten, and geology becomes an inductive science.

The dynamics of geology have too often been formed or constructed from what may be termed *the possibles*. It is evident, however, that they can not be true because they are possible; it only saves them from absurdity. The truth of our dynamics is to be tested by their conformity to the statics of a region in each particular case.

As an instance illustrative of this kind of error, I may cite

the ingenious explanations which were offered to explain the easterly dipping of the quartz, limestone and slate rocks of Berkshire, Mass., beneath the gneiss of the Hoosick mountain. But this does not exist immediately adjacent to the range; there is a synclinal axis, the dip being westerly and from the range. The error in the dynamics arose from having determined the statics only in part.

Among the points in statical geology which always require considerate attention, is the derivation of the materials composing a formation or mass, when mica and talc enter into their composition. In cases when those minerals compose a rock, we might infer that it was metamorphic; especially when they exist in large proportions. But such a conclusion becomes doubtful if other facts in the statics of those rocks are wanting; for mica and talc from the form of their particles, and the nature of their constitution, reproduce the same lithological masses as those from which they were derived. Hence it is certainly safe to be cautious in pronouncing a rock metamorphic when composed of mica and talc.

There are three kinds of forces which are recognizable in the earth's crust; physical, chemical and biological. The first leaves its imprint upon its masses, and from those imprints its nature and its degree are inferential.

The second furnishes results generally complete, and activity is rather inferential, and our conlusions must be based upon our knowledge of chemical principles, and the known mutual action of bodies upon each other. Chemical forces must frequently give origin to the physical, and they no doubt become the source of some of the most energetic of this class of operations.

The third is entirely passive, leaves no mechanical impress, but they leave memorials of the highest moment. Biological forces are entirely passive when put in conflict with the dynamical and chemical, and always yield to their movements.

It is in the construction of the globe that these forces are to be studied, and it is here that the conditions are revealed

Emmons, Ebenezer,
1799-1863,
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containing a statement of
the principles of the

1854.